CONTROL

SYSTEMS · INSTRUMENTATION · DATA PROCESSING · ENGINEERING · APPLICATIONS

A TECHNICAL JOURNAL FOR DESIGNERS AND USERS OF ELECTRICAL, ELECTRONIC, HYDRAULIC, MECHANICAL AND PNEUMATIC CONTROL SYSTEMS AND INSTRUMENTATION

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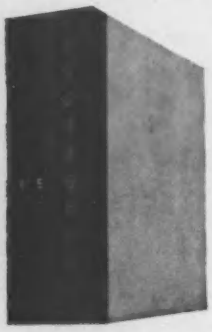

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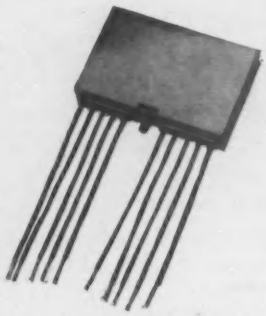

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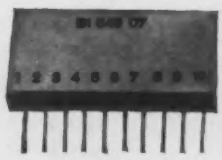

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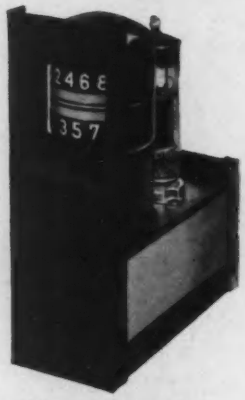

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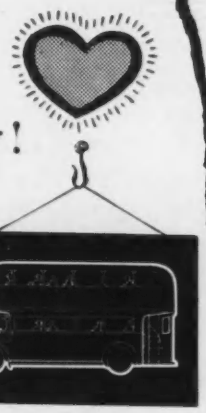

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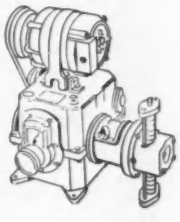

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CONTROL
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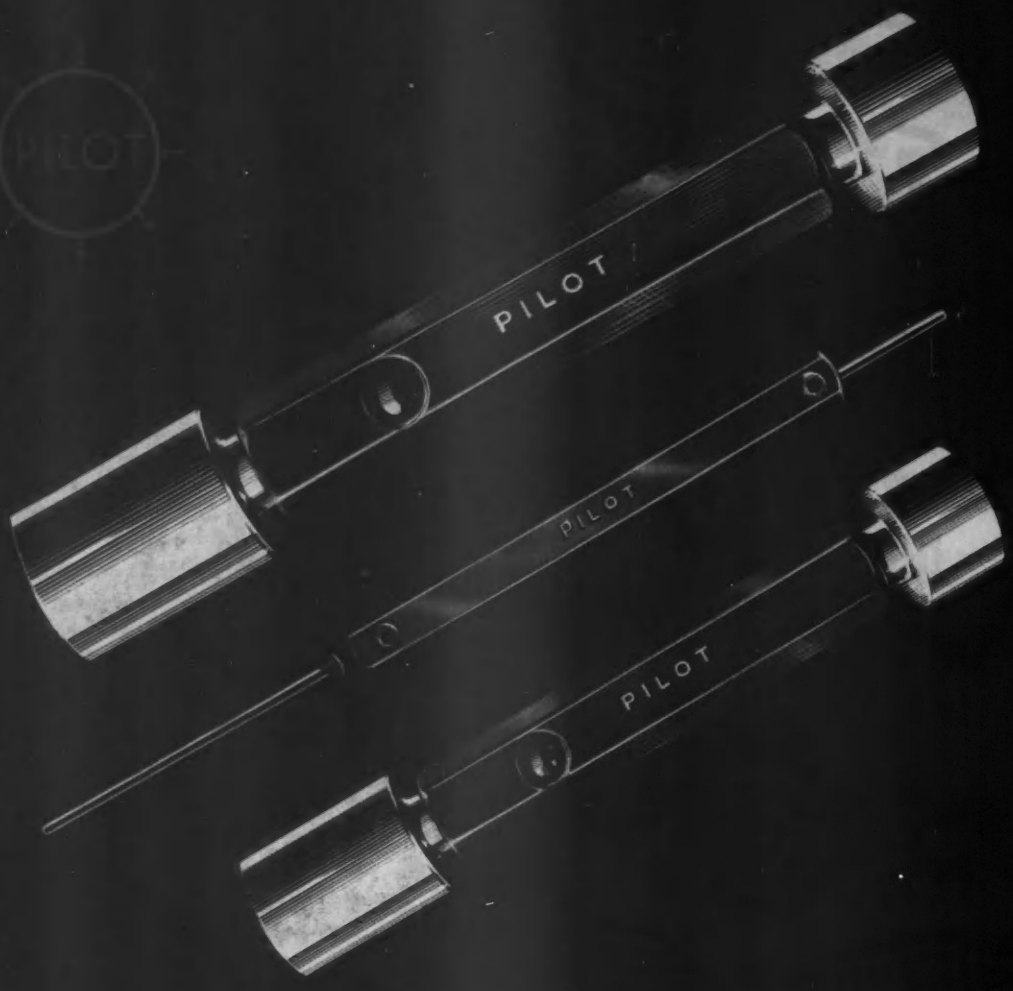
CONTROL AND BEER

Brewers, like everyone else, have problems. The British beer drinker—be he a draught or bottled type—is a connoisseur and if his favourite brand deviates in the slightest from the norm the brewers soon know about it in terms of falling sales. For centuries, beer of unsurpassed quality has been made in traditional ways with little or no help from science but, today, rising costs are making these methods too expensive. It is the old problem of keeping down the price while maintaining quality.

On page 98 of this issue we commence an important article by Dr. Kilkenny in which he shows how control systems and instrumentation are being increasingly applied to this important and traditional craft. Not all the brewers' control problems are yet solved however and Dr. Kilkenny does a great service to the control industry by indicating several points in the complicated flow chart where improved or even completely new control devices are badly needed.

Our article on the brewing industry is just the first of a series we have planned. This will, we hope, eventually cover all of the important process industries. The articles will have two main functions. They will both draw the attention of the instrumentation industries to the problems and requirements of their potential customers and also help the process industries to help themselves. These industries tend to work in watertight compartments, although comparatively few control problems are so specific as to be confined to one type of plant. For example, in the next instalment of his article Dr. Kilkenny writes about some control problems in beer bottle washing. This is not really brewing at all and exactly the same question crops up in several industries. A study of the series by both the supplier and user of control equipment should prove rewarding to both.



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Sir!

The Editor welcomes correspondence for publication.

Teaching transforms

SIR: In Dr. MacLellan's comments on my letter* regarding Laplace Transform techniques he states that in his experience the algebra involved causes the mathematically inclined student little difficulty and sees little value in a student learning how to derive or use transform pairs. However, our attentions are not directed to such students but to engineers and here I suggest simplifying techniques and plausibility arguments are necessary. Also, since the Laplace Transform method is algebraic in application, I would consider this to rest on even more familiar ground than that of differential equations.

The significance of Laplace is no less obscure than that of solving differential equations: how many students could assign physical significance to solutions involving the D operator which involve algebraic manipulations and an appeal to previously established results? Although Laplace does not give transient and steady state solutions separately these can generally easily be resolved by reference to the physical problem. An additional advantage is that the transient due to initial conditions is available explicitly. However, Laplace has its limitations and these should be made apparent to the student.

I would like to affirm quite strongly that I feel we are doing a disservice to students if we do not introduce Laplace methods. Apart from a discussion of the relative merits of Laplace versus differential equations, which is to some extent a matter of personal opinion and perhaps prejudice, we must face the fact that by far the greater volume of published work is based on Laplace Transform methods and would otherwise be out of reach of the student, e.g. the literature on sampled data systems, digital servos and computerized machine tool applications.

Wimbledon Technical College N. G. MEADOWS

*See September's issue of CONTROL.

Bored by the board?

SIR: Mr. Ford's stimulating article on page 65 of the June number of CONTROL, 'Us or U.S.' does not get down to the root of the matter. This is mainly a question of the amount of attention paid to design. Production engineering is well catered for, not only in industry but by educational establishments, and by professional institutions devoted to it. Besides this there are good technical journals dealing with almost every aspect of production and manufacture, though most of these take the product drawings as a starting point.

Going back beyond this we find that—by comparison—no attention at all is paid to design, or to the place where quality, if it is to be achieved at all, must be injected in the product—the drawing board.

Neither the university schools of engineering, nor the Colleges of Advanced Technology seem to take any interest in it. It is hardly mentioned in their prospectuses, which I have been studying recently. The professional institutions seem to have lost all interest in it, and most of them have dropped engineering drawing and design from their qualifying examinations. By comparison with, e.g. Germany

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Continued from page 77

Sir!

or the U.S.A. we have no technical journals dealing with it at an effective level.

These, and the predominant financial rather than professional control of industry, are some of the main reasons for our rapidly increasing dependence on manufacturing foreign designs under licence, with all that this involves in the erosion (to a very dangerous point) of our own creative ability.

One can only hope that it is not too late for the country as a whole to initiate recovery by taking these matters seriously.

London H. CLAUSEN

● *One argument against the teaching of engineering drawing is that the subject is not fundamental, and that it deals with more or less transient conventions. But some drawing conventions are at least as important as, say, the sign conventions used elsewhere. Certainly much of the work of design must be done on the board, and we agree that this may be in danger of being forgotten.*—EDITOR.

Uncivil leader

SIR: Your leading article, 'Society Tangle,' published in the September issue of CONTROL, seemed to me to state its case well enough, but I was dismayed by your choice of the Mechanicals and Electricals as sole sources of high qualification for a British control engineer, and the implication that the Civils count for nothing in this field.

I believe that there is a good deal of systems engineering done by civil engineers, and although sophisticated notions like 'feedback' are not part of their everyday stock-in-trade, I take it that you would not therefore say that they know nothing about, or have nothing to do with, control.

Rochester T. G. WHITEHOUSE

● *Of course control comes into civil engineering. We did not mention the Civils individually, but we know that, like the other members of the B.C.A.C., they are interested in control matters. Our criticism of the B.C.A.C. still stands.*—EDITOR.

Farewell

SIR: I am sorry to see that your founder-editor has left. I have been a reader of CONTROL almost since it began life, and in that short time I have learned to regard the journal as one of each month's more agreeable events. You say in your 'Publisher's Column' that Mr. Rivington has given the magazine a good start. I am sure that many other readers will join me in endorsing that statement. As one of the humbler readers who have particularly enjoyed the editorials, may I ask you to convey my good wishes to him? Good wishes also to CONTROL under its new Editorship.

Reading J. PETER CRABBE

● *Thank you. Yours is typical of other readers' letters wishing Rivington well in his new venture.*—EDITOR.

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CONTROL

OCTOBER 1959 VOL 2 NO 16

The dismal dimension

THE systems engineer is one of the most important products of industrial evolution. He knows something about each component of the system he studies, and is very much aware that the whole is more than the sum of its parts. He knows how the organs of his system would behave as individuals in an ideal world, and he knows, or tries to find out, how they interact in a real one. While he understands well enough the blocks in his block diagrams, he does not get so close to them that he cannot see the loops for the knots.

The systems engineer probably gained his early technical education in the same sort of institution as any other engineer. He was taught general dynamics, and then, according to his bent, he concentrated his attention more especially on the solid-mechanical, fluid-mechanical or electromagnetic forces. Having learnt about the generation and use of power, he became involved in the control of large powers by means employing small powers. Eventually he found himself considering, not merely isolated machines, but whole plants and processes.

In his student days he was taught to be objective. Not for him the sophistication of physicists who asserted the inseparability of observer and object. On the engineer's scale this particular interaction did not matter. Perhaps there was uncertainty about the speed and position of single electrons, but there was no such uncertainty about electric motors. Station and motion were determinate, controllable, fixed by the laws of Newton, Faraday and others. The working parts of a machine were adequately studied, analysed and designed in terms of such fundamental dimensions as mass, length, time and electric current. Systems, for the student concerned with them, were dealt with in terms of the same physical dimensions.

There is one dimension that finds no place, however, in the formal education of most engineers, a fundamental unit that is vitally important not only in the systems that are studied with such austere objectivity, but also in the system in which the engineer is himself caught up. The fundamental unit that we are, most of us, so concerned with in private life, but that is omitted from nearly all technical curricula, is the unit of money, and the system in which we are all caught up is the economic system.

Usually engineers have to learn about engineering costs after they have left college, yet (outside the military sphere), the costs nearly always determine how a job is done. Have we not here put our finger on a fundamental flaw in the technological education given in our country to-day? Why is there this feeling that money is too sordid for mention in a course of applied science or engineering? So often, when a young engineer is inroduced to a real-life problem of finding a best or 'optimum' system, he expects that the criterion will be measured in terms solely of fundamental dimensions like mass, length, time and electric current. It will not. The criterion will *definitely* involve cost; it *may* also involve some of the other fundamental dimensions. To take a single example, the optimum design of a power station is that which produces energy at the lowest cost per kilowatt-hour, not the design which generates at the highest thermal efficiency.

Perhaps this neglect to teach the economic facts of industrial life to engineers accounts, at least partly, for their failure to rise as high in the industrial organization of the country as, say, accountants. We often hear the complaint that engineers do not reach the top levels of management, and that this is a fault of the way in which industry is run. But, in a society measuring values as ours does, is it not rather a fair reflexion on the economic innocence of engineers?

The distaste for the cost dimension is deeply ingrained in our technical teaching staffs, and we cannot hope to remove it at a blow. What is the solution? Surely it is the teaching of systems engineering. The economic organization of a country or business is a first-class example of an interacting system, and if it is introduced as such it need not offend the most pure-minded of lecturers. Economics has been derided as the 'dismal science.' Perhaps, if more systems engineers got down to a serious study of it, they might even brighten the subject up.

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INDUSTRY'S VIEWPOINT

A monthly article by a prominent man in the control industry on a subject chosen by himself

Cambridge Instrument's Managing Director, H. C. Pritchard, wants further advances in measuring techniques because . . .

MEASUREMENT IS ESSENTIAL FOR CONTROL

The post-war years have seen extremely rapid advances in computers and control mechanisms. Servo theory and digital and analogue techniques have vied with nuclear physics and space research in exciting the imagination of the young scientist and the go-ahead technician. In themselves such trends are wholly admirable, but the importance of measuring techniques in these and other fields has received inadequate attention.

Measuring techniques are an essential factor in a control system. The requirements in an automatic system as regards its dynamic properties are not usually the same as for manual control. This is not adequately recognized. Insufficient consideration is given to the selection of what is to be measured, and the choice too often falls on what can be measured already. With automatic control the accuracy achieved depends more often on the accuracy of measurement than on the precision of the control system itself. The basic reliability required is of a high order, and generally the effect of removing the human operator, with his flexibility and wide range of response times, is underestimated.

In instruments for scientific work, most of the early research and much of the development was done in university and other laboratories, and not in the instrument industry itself. The speculative aspect was absent before the instrument industry in general became involved—a somewhat different case from that of instruments required specifically for industry. The price which most customers expect to pay for an instrument system is determined more by its apparent simplicity, size and number of component parts than by the research and development expenditure involved, or by the result which is achieved for the customer.

The advances made in recent years in servo theory and its application, and in computing methods, have not been matched by advances in measurement, and the need for more work on measurement for industrial control is, unquestionably, long overdue.

How can this greater effort be provided? Higher investment in research by the instrument companies themselves is one answer, although research expenditure by the instrument industry is already about 5½% of turnover. Nevertheless, more might be done by some.

Further, as many advances in measurement for scientific purposes have originated in our universities, perhaps the new Colleges of Advanced Technology can provide a similar contribution. It may be that the Research Associations can do more.

Some user industries have made notable contributions and derived great benefit from them. But a more widespread appreciation could be generated, and there could be enhanced co-operation between the instrument and user industries. This might be along the lines suggested by John Bolton in his article 'Partnership in Automation' which appeared in CONTROL for February 1959. Coming nearer home, the user industries could offer more contributions to CONTROL.

However, my purpose is not to give the answers but to put a viewpoint. If readers feel that it is valid, I hope and expect that they will stimulate progress in the right direction.

H. C. Pritchard

A wind-tunnel servo for stagnation pressure

by **H. FUCHS**, B.SC., PH.D.
and **D. WHEABLE**, GRAD.I.E.E., A.M.INST.E.
Blackburn Electronics Ltd.

IN THE DESIGN OF MODERN AIRCRAFT A CONSIDERABLE number of wind tunnel model tests have to be carried out to assess the aerodynamic characteristics of the structures and shapes to be used. Such work includes the measurement of the three rotational couples, and the three translational forces applied to the airframe at various angles of incidence and Mach numbers of the model, as well as such special applications as pressure plotting and assessing the flutter characteristics of a structure. With the increasing speed of modern aircraft, the requirement also exists for the wind tunnel to work at higher Mach numbers. The Blackburn high speed wind tunnel was designed initially, to work in the transonic range Mach 0·6 to 1·4, but will be extended in the near future to cover speeds up to Mach 3·5.

Owing to the economics of constructing such tunnels and the enormous energy required to generate such high speeds over a substantial working section (27 in. × 27 in. in the case of the Blackburn tunnel), it is practice to make these tunnels on the blow-down principle. A typical arrangement is shown in Fig. 1. Reservoir R is pumped up to some 30 atm using a relatively low power pump, the operation taking about 4½ hours. The model to be tested is placed in the working section W and the valve H opened in such a way as to keep the pressure in the settling chamber S constant. Subsonically the Mach number is set by throat T2, transonically and supersonically by throat T1.

The servo to be described is used to keep the stagnation pressure in the settling chamber constant, thus ensuring constant conditions in the tunnel during the run.

Typically, a run may last from 15 to 20 sec, during which time automatic high-speed pen recorders store the quantities of interest. Should the stagnation pressure be allowed to vary during the run, computation on the recorded data becomes very great and it is not possible to run through a series of measurements under constant conditions.

System description

The basis of the system for holding the stagnation pressure constant, as first proposed, is simple, and is shown diagrammatically in Fig. 2. The stagnation pressure P_s is measured by a pressure transducer T having the required linearity, range and resolution. The electrical output from this transducer is compared with a reference voltage V_R and the difference between these two voltages, after amplification, is fed to an electrohydraulic valve M. This in turn, feeds an hydraulic ram, operating the air valve H.

The pressure transducer chosen was the Statham 0–100 lb/in² unbonded strain gauge differential transducer, having a linearity of 0·1%, a temperature coefficient of 0·001% per °C and a resistance of 600 ohms. With 7 V energization, it gave an output of 350 μV/lb/in² differential pressure.

Performance

Two points immediately presented themselves as requiring solution:

a. How will the loop gain vary as the reservoir pressure drops?

b. What are the transfer functions of the various fixed components of the tunnel, i.e. the valve H acting as a position servo, and the tunnel acting as a pressure integrator?

The control valve response

The valve chosen to control the air flow is manufactured by the Harland Valve Co., and comprises a 24 in. plug which is rotated by means of an hydraulic differential jack carrying a 5¼ in. piston.

The jack is operated by a Moog electrohydraulic valve giving a maximum flow of 4½ gal/min at 8 mA differential input current, the flow being proportional to the input current. Such an arrangement, shown in Fig. 2, may be described by the equation

$$x = \frac{S_p}{d_m} \int I \, dt \qquad \ldots (1)$$

The device behaves as an integrator, and over a subtial range gives 90° of phase lag.

To reduce the phase lag of this sub-system, it was decided to incorporate feedback around the Harland-Moog valve combination, converting it from a rate to a position servo. This is shown schematically in Fig. 3. A potentiometer was attached to the main Harland plug, providing a voltage proportional to ram position.

The voltage at the ram is given by the equation

$$d_m C_1 \frac{dV_o}{dt} + gS_pV_o = gS_pV_1 \qquad \ldots (2)$$

Eq. 2 may be re-written as a transfer function as follows

$$\frac{\overline{V}_o}{\overline{V}_i} = \frac{1}{\frac{d_m C_1}{gS_p}S + 1} \qquad \ldots (3)$$

with a time constant of $T_1 = d_m C_1 / gS_p$

The full equations for the response of the Harland valve servo are given in Appendix 1.

Settling chamber response

Referring to Fig. 4 the mass flow through the Harland valve is given by $M_1 = K_1 A_1 P_R$ ... (4)

The mass flow into the working section W is given by

$$M_2 = K_2 A_2 P_S \qquad \ldots (5)$$

From simple aerodynamic consideration the equation for the settling chamber pressure P_S, assuming isothermal conditions, becomes

$$K_1 A_1 P_R = \frac{M_S}{P_S} \cdot \frac{dP_S}{dt} + K_2 A_2 P_S \qquad \ldots (6)$$

since M_S/P_S is a constant for a given vessel (in this case the settling chamber).

This gives a linear first order equation in P_S and may be re-written as a transfer function.

$$\frac{P_S}{A_1} = \frac{\left(\frac{K_1 P_R}{K_2 A_2}\right)}{\left(\frac{M_S}{P_S K_2 A_2}s + 1\right)} \qquad \ldots (7)$$

with a time constant $T_2 = M_S / P_S K_2 A_2$

The full equations of the response of the settling chamber are given in Appendix 2.

Block diagram of complete system

The block diagram of the complete system is shown in Fig. 5. Starting at the left-hand side, the stagnation pressure P_S is measured by the pressure transducer T,

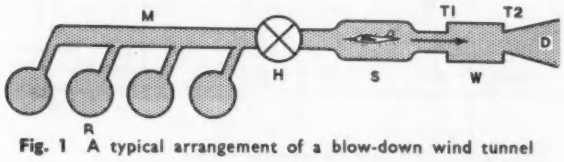
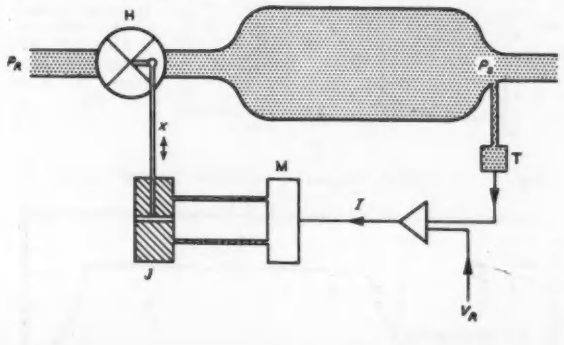


Fig. 1 A typical arrangement of a blow-down wind tunnel

Fig. 2 The basis of the system, as first proposed, for holding the stagnation pressure constant



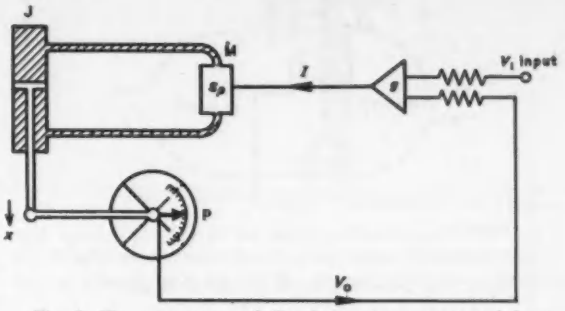


Fig. 3 The rate servo of Fig. 2 has been converted here into a position servo by incorporating feedback

Fig. 4 The parameters in the settling chamber

and the output voltage after amplification compared with reference voltage V_R.

After further amplification the error signal is fed to the shaping network X, whose function is so to affect the frequency response of the overall loop as to maintain stability against oscillations under all conditions. Its detailed design will be dealt with later. The error signal then passes through the Moog-Harland valve combination which produces valve 'open area' as its output. Then follows the pressure transfer function of the settling chamber, which in turn feeds back to the pressure transducer.

From Appendix 2, it is seen that $T_1 = 0{\cdot}72$ sec, and $T_2 = 1{\cdot}18$ sec.

It is therefore evident that without any other frequency sensitivity elements in the loop and with a loop gain >1, this loop is unstable since it contains 180° of phase shift, at about 1 c/s. Further it will be seen from Eq. 7 that as the reservoir pressure runs down, the gain of the settling chamber transfer function changes. It is therefore necessary to introduce at X a transfer function of such form as to cancel approximately 90° of phase shift, over such a frequency range as to permit the remaining transfer function to reduce the gain to < 1. It is also necessary to introduce a programmed gain change during the tunnel run, so as to cancel the change in gain in the settling chamber, introduced by the term P_R in the numerator of Eq. 7.

Stabilizing the main servo against oscillations

After establishment of the type of transfer function to be expected from the fixed components in the main loop and also their approximate time constant, the servo loop was closed but without any shaping at X. During the ensuing tunnel run, oscillatory conditions were experienced and measurements of phase and amplitude were taken at the Harland valve and at the pressure transducer. From these measurements it was possible to establish an exact phase lag and gain figure

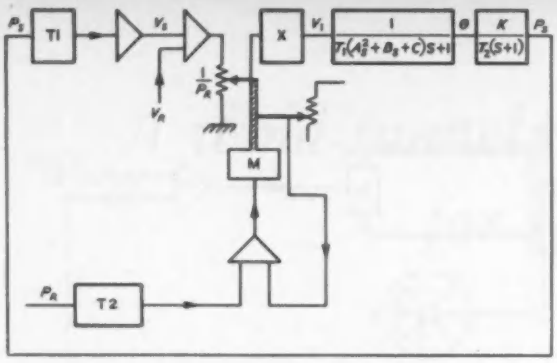


Fig. 5 The block diagram of the complete system

for the settling chamber. A d.c. analogue, using two computing amplifiers as shown in Fig. 7, was then set up to give as close an approximation to the performance of the settling chamber as possible, and this was introduced into the loop at a convenient point.

Phase advance circuits were incorporated at X until stabilization of the loop had been achieved. Fig. 6 shows the circuit used and Fig. 8 the frequency-amplitude characteristics of the shaping introduced at X.

Subsequent to these measurements further tunnel runs were carried out, which substantiated the correctness of the assumptions and the efficiency of the stabilizing networks.

At some later date, however, bleed-off from the settling chamber was introduced to provide boundary layer control in the working section.

Eq. 7 indicates that an increase in area A_2, which is in effect the same as introducing a second throat for exit from the settling chamber, has the effect of reducing the time constant, and hence the attenuation and phase lag at a given frequency.

The effect of bleed was to introduce an increase of some 30% in A_2, and this was compensated, but reducing the phase advance at X.

Gain variations with reservoir pressure

Eq. 7 indicates that the overall loop gain varies directly as reservoir pressure P_R. It was decided to vary the gain of the main error amplifier, inversely with the reservoir pressure, in order to cancel this effect. A pressure transducer T2, of the same type as used in the settling chamber, was introduced into the reservoir manifold and its output voltage was arranged to position a servo shaft. On this shaft was mounted a potentiometer introduced into the main control loop. Variations of reservoir pressure from 30 atm to 2 atm gave variations in gain from 1/15 to 1. During subsequent tunnel running it was discovered that, although an adequate gain margin existed at the beginning of the tunnel run, it was possible for the servo to oscillate at the end of the run. This indicated that the gain variations were not as great as suggested by Eq. 7. Analysis of the form shown in Appendix 2 suggested that the gain varied as $P_R^{0.85}$. In view of this, it was decided to make the gain vary as $P_R^{0.5}$, and to this end a gain change from $\frac{1}{4}$ to 1 was introduced for pressure variations from 30 atm to 2 atm.

This change was found to give satisfactory stability, and running conditions, at all reservoir pressures.

Fig. 9 is a typical stagnation pressure record during a tunnel run, and shows the accuracy of pressure holding as $\pm 0{\cdot}3\%$.

Conclusion

The wind tunnel controller, as described above, has been working satisfactorily for some nine months, operating at about two runs per day. Serviceability, after an initial shake-down period, is very good. A design programme has now been initiated to extend the facilities of the controller, to include a programmed Mach-number change during a run. Further work is continuing to improve the accuracy of pressure-holding from $\pm 0{\cdot}3\%$ to $\pm 0{\cdot}05\%$ of full scale.

APPENDIX 1

Full equations of Moog-Harland valve system

Referring to Fig. 3 the mass flow of oil from the Moog valve is given by $Q_p = IS_p = V_1 S_p g$. The mass flow into the Harland ram is given by $Q_m = d_m x$. The mass flow due to leakage is given by $Q_L = LP$. The mass flow due to the bulk modulus of the oil is given by $Q_B = (V/B) \cdot (dp/dt)$.
Hence

$$Q_p = Q_m + Q_L = Q_B$$

and

$$S_p g \overline{V}_1 = \left(d_m + \frac{LM}{d_m} S + \frac{VM}{d_m B} S^2 \right) S \overline{x}$$

or writing $C_1 \overline{V}_o = \overline{x}$

$$S_p g \overline{V}_1 = \left(d_m + \frac{LM}{d_m} S + \frac{VM}{d_m L} S^2 \right) S C_1 \overline{V}_o$$

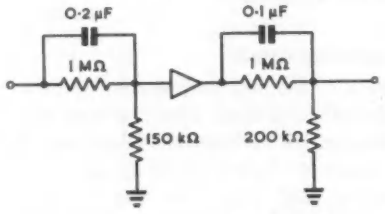


Fig. 6 A circuit diagram of the shaping network shown as X in Fig. 5

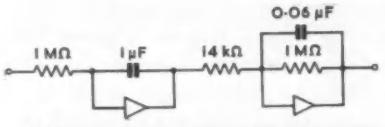


Fig. 7 The analogue for the tunnel used in stability tests

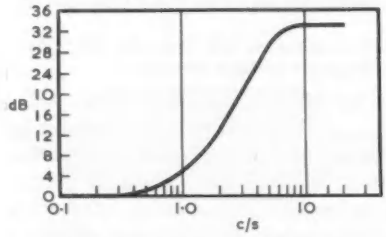
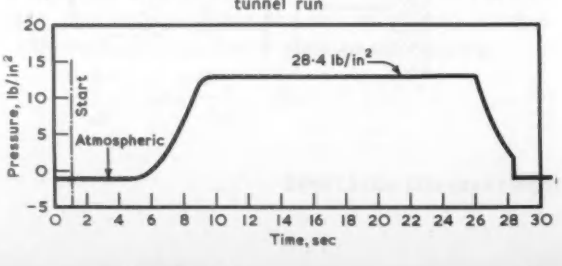


Fig. 8 The frequency - amplitude characteristics of the shaping introduced at X in Fig. 5

Fig. 9 A typical stagnation pressure record during a tunnel run



Applying feedback around the Moog amplifier gives

$$S_p g(\bar{V}_1 - \bar{V}_o) = \left(d_m + \frac{LM}{d_m}S + \frac{VM}{d_m B}S^2\right) SC_1\bar{V}_o$$

which yields the transfer function

$$\frac{\bar{V}_o}{\bar{V}_1} = \frac{S_p g}{d_m}\left[\frac{1}{C_1\left(1 + \frac{LM}{d_m{}^2}S + \frac{VM}{d_m{}^2 B}S^2\right)S + \frac{S_p g}{d_m}}\right]$$

If the leakage and bulk modulus flow is ignored, this yields Eq. 3.

$S_p = 290{,}000$ in³/min; $A = 4{\cdot}83$ in³/sec-mA; $d_m = 17{\cdot}7$ in²; $g = 6$ mA/V; $C_1 = 1{\cdot}205$ in./V; hence $T_1 = 0{\cdot}72$ sec.

APPENDIX 2

Derivation of transfer function of the settling chamber

Referring to Fig. 4 the mass flow through area A_1, assuming choked conditions, is given by

$$Q_1 = \rho_1 A_1 V_1 = \rho_1 A_1 a_1 = \sqrt{(\gamma p_1 \rho_1 A_1)} = \gamma^{\frac{1}{2}} C^{-\frac{1}{2\gamma}} P_1 \left(\frac{\gamma+1}{2\gamma}\right) A_1$$

Also using Bernoulli's equations for adiabatic flow from the reservoir to the orifice A_1

$$\left(\frac{\gamma}{\gamma+1}\right)\frac{P_R}{\rho_R} = \left(\frac{\gamma}{\gamma-1}\right)\frac{P_1}{\rho_1} + \frac{\gamma P_1}{2\rho_1}$$

$$\text{or} \quad P_R = \left(\frac{\gamma+1}{2}\right)^{\frac{\gamma}{\gamma-1}} P_1$$

$$\text{hence} \quad Q_1 = \gamma^{\frac{1}{2}} C^{-\frac{1}{2\gamma}} \left(\frac{2}{\gamma+1}\right)^{\left[\frac{\gamma+1}{2(\gamma-1)}\right]} A_1 P_R \left(\frac{\gamma+1}{2\gamma}\right)$$

The mass flow into the working section assuming choked conditions is given by

$$Q_2 = \rho_2 A_2 V_2 = \rho_2 A_2 a_2 = \sqrt{(\gamma \rho_2 P_2)} A_2$$

Assuming isothermal conditions (because of the relatively small expansion)

Applying Bernoulli's equation for isothermal flow

$$P_S = e^{-\frac{\gamma}{2}} P_2$$

$$\text{Therefore} \quad Q_2 = \left(\frac{\gamma}{K}\right)^{\frac{1}{2}} e^{\frac{\gamma}{2}} A_2 P_S$$

This gives the equations of mass flow

$$\frac{V}{K}\frac{dP_S}{dt} = \gamma^{\frac{1}{2}} C^{-\frac{1}{2\gamma}} \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{2(\gamma-1)}} A_1 P_R \left(\frac{\gamma+1}{2\gamma}\right) - \sqrt{\left(\frac{\gamma}{K}\right)} e^{-\frac{\gamma}{2}} A_2 P_S$$

This is a linear differential equation in P_S and yields the transfer function

$$\frac{P_S}{A_1} = \gamma^{\frac{1}{2}} \frac{C^{-\frac{1}{2\gamma}} \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{2(\gamma-1)}} \left(\frac{\gamma+1}{2\gamma}\right) P_R}{\frac{V}{K}S + \sqrt{\left(\frac{\gamma}{K}e^{-\frac{\gamma}{2}}\right)} A_2}$$

which may be written as $K_1 P_R{}^{0{\cdot}85}/(T_2 S + 1)$

with $T_2 = (V/A_2\sqrt{\gamma K})\, e^{\frac{\gamma}{2}}$

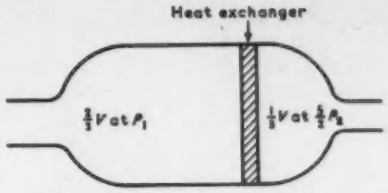


Fig. 10 Settling chamber arrangement

If bleed is applied to the settling chamber as in the case in the Blackburn tunnel, this has the effect of apparently enlarging area A_2 and reduces the time constant proportionally.

$V = 22 \times 16\pi$ ft³. $e^{\frac{\gamma}{2}} = 2{\cdot}014$. $A_2 = 5{\cdot}06$ ft². $\gamma = 1{\cdot}4$. $K = (RT) = 890{,}000$. $T_2 = 0{\cdot}393$ sec.

Owing to the fact that a heat exchanger is installed about ⅓ of the way down the settling chamber (Fig. 10) it transpires that the pressure is not uniform over the whole volume. In fact, it appears that the pressure ratio up stream to down stream of the heat exchanger is always some 5/2. This results in an effective increase of the settling chamber volume of

$$V' = \left(\frac{2}{3}V + \frac{5}{2}\cdot\frac{1}{3}V\right) = \frac{3}{2}V$$

This gives the new time constant as $T_2' = 1{\cdot}18$ sec.

List of symbols

x = ram displacement
I = input current to Moog valve in mA
S_p = flow in in³/sec per unit current to Moog valve
d_m = cross sectional area of Harland ram in in²
C_1 = constant converting ram displacement to output volts in in/V
g = gain of Moog amplifier in mA/V
K_1 = constant giving mass flow of air at Harland valve
K_2 = constant giving mass flow of air at working section (1st throat)
A_1 = open area of Harland valve
A_2 = open area of 1st throat
P_R = instantaneous reservoir pressure
P_S = instaneous settling chamber stagnation pressure
M_S = instaneous mass of air in settling chamber
C_2 = constant converting Harland ram displacement to Harland valve open area, in in²/in
L = leakage constant for Harland ram in in³ of oil per lb/in²
B = bulk modulus of oil
M = effective inertial mass at Harland ram
V = total oil under compression in hydraulic system
Q_p = mass flow out of Moog valve
Q_m = flow into Harland ram
Q_B = flow due to compression of oil
Q_L = flow due to leakage
s = Laplacian operator
V_1 = input voltage to Moog amplifier
V_o = output voltage from Harland valve potentiometer
M_1 = mass flow of air into settling chamber
M_2 = mass flow of air out of settling chamber
P = instantaneous hydraulic pressure in Harland jack
ρ_1 = density of air at inlet to settling chamber
ρ_2 = density of air at outlet to settling chamber
V_1 = velocity of air at inlet to settling chamber
V_2 = velocity of air at outlet to settling chamber
γ = ratio of specific heats of air
a_1 = velocity of sound at inlet to settling chamber
P_1 = pressure at inlet to settling chamber
Q_1 = mass flow of air into settling chamber

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Electrically powered process control instruments call for electrically powered valves

Electrically operated throttling valves

by **GLENN F. BROCKETT,**
Fisher Governor Co., Marshalltown, Iowa, U.S.A.

IT IS EVIDENT THAT THE USE OF ELECTRICALLY-POWERED process control instruments and instrument systems will increase materially in the coming years. Most of the major British, European and U.S. instrument manufacturers have announced or are developing a line of electrical-electronic instruments. In the past year, nearly all of the major oil and chemical companies building new plants or plant expansions, have considered the use of electrical instruments in preference to pneumatic, and in many cases, the decision has gone to the electrical system. This will occur increasingly in the future.

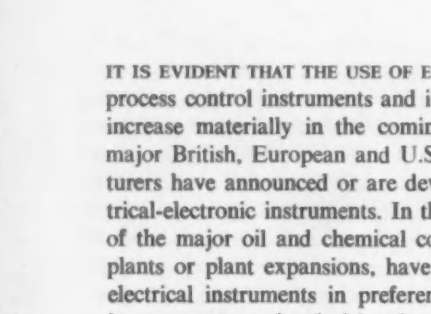


Fig. 1 (above) Block diagram of Conoflow electric valve actuator

Fig. 2 (right) Conoflow electrically powered valve

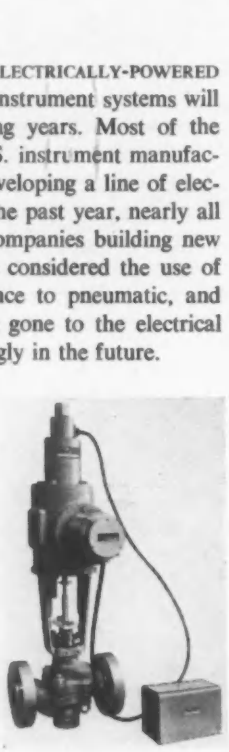
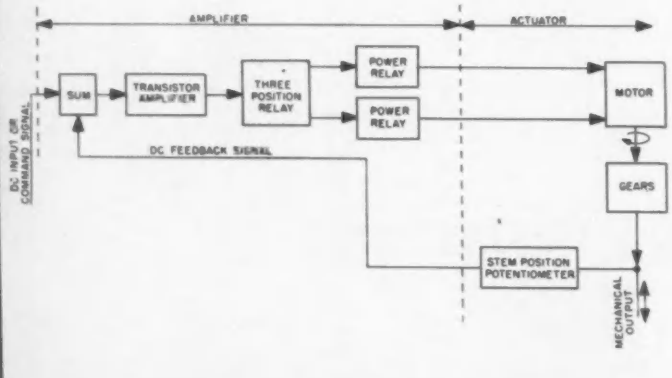


Fig. 3 Block diagram of Norwood Controls valve actuator



When electrically-powered instruments are used, it would seem desirable to use electrically powered valves also, and thus eliminate the instrument air system entirely. As a result of this obvious need, most control valve manufacturers have spent a great deal of time and money in the development of electrically powered valve operators. These developments have taken three general directions: these are the geared electric motor, the electrohydraulic system, and the thermal-electric device.

Geared electric motors

The most obvious approach is to use an electric motor and a gear system. Remotely-operated stop valves are an example of this approach, although these valves are not meant to operate continuously in response to a millivolt or milliamp signal from a controlling instrument and, consequently, do not fall within the definition of control valves. There are, however, at least two American manufacturers who offer control valve operators powered directly by electric motors through gears.

Conoflow Corp., Philadelphia, Pa., produces one such operator. Fig. 1 is a block diagram of its principal components, and Fig. 2 an exterior picture. This operator responds to a milliamp control signal, and throttles continuously. The control signal operates a moving coil permanent magnet type of force motor. The coil of the force motor is linked mechanically to the core of a linear differential voltage transformer, which serves as a null-type motion detector. The secondary output current produced by the motion detector is fed to an amplifier to operate one of two relays. The relays apply 100-volt a.c. to either the forward or reverse windings of a low inertia electric motor. The motor drives the valve stem through a linear motion gearbox. A force-balanced type of feedback is accomplished by a spring attached to the valve stem, which resets the core of the linear differential voltage transformer and the coil of the force motor to the null position. The position of the valve stem is thus directly proportional to the magnitude of the control signal at all times.

The amplifier and relay box, which is connected to the operator by cables, may be located anywhere between the controlling instrument and the valve. This operator is available with strokes from $\frac{1}{4}$ in. to 4 in., and is said to have a stroking speed of 4 in./min. at 500 lb maximum thrust. It has a $\frac{1}{8}$ h.p. motor.

Norwood Controls Division of Detroit Controls Company also offers an all-electric geared operator. It differs in principle from the Conoflow in that it uses a summing-type amplifier in place of a force motor and linear differential voltage transformer. Also, feedback is accomplished electrically from a stem position potentiometer feeding back into the summing circuit. A block diagram of the unit, which is available with thrusts up to 1000 lb and is powered by a 1/40 h.p. electric motor, is shown in Fig. 3.

The all-electric geared motor operator has the advantage of the power input being employed directly, without conversion to another operating medium. This would logically result in savings in conversion component costs, conversion inefficiencies and complexity. However, there are some fundamental problems. The maximum torque that can be exerted by the rotor of an electromagnetic machine is a function of the strength of the magnetic field which is created. If we consider even the most desirable of magnetic materials, we find that we can achieve a maximum effective 'magnetic pressure' of the order of 50 lb/in². On the other hand, if we are to get good frequency response and speed of operation, the inertia of the rotor must be low. It follows that a combination of high stem thrusts and rapid response in a device of this type is difficult to obtain.

In addition to the fundamental disadvantage in the torque-to-inertia ratio, we are also faced with the problem of providing satisfactory gearing without backlash between the motor and the valve stem. These two basic objections have caused most designers to turn to the electro-hydraulic approach.

Electro-hydraulic operators

The general principle of the electro-hydraulic operator is shown in Fig. 4. In this system, an electric-motor-driven pump provides a continuous source of high pressure fluid for positioning the main operator piston. The flow of oil to the piston is regulated by a hydraulic servo-valve, this being actuated by a force motor in response to the signal from the controlling instrument. A force-balance type of feedback is accomplished through a spring which is loaded by movement of the main valve stem to reset the force motor and the servo.

The first commercial adaptation of this principle was marketed by Manning, Maxwell & Moore, Stratford, Conn. A schematic diagram of this operator is shown in Fig. 5, and an exterior view of the operator, mounted on a valve, in Fig. 6.

This operator is powered by a $\frac{1}{4}$ h.p. electric motor which runs continuously and drives a rotary gear pump. The hydraulic system consists of the pump, a relief

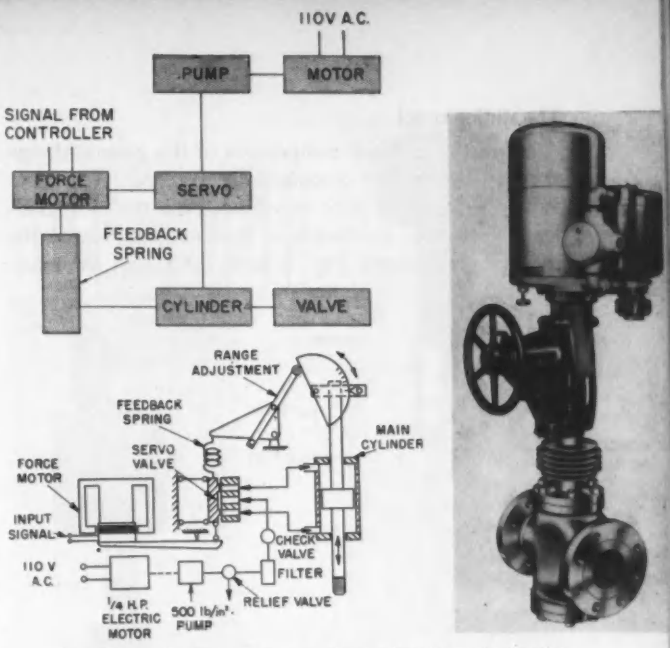


Fig. 4 (top) Block diagram of simple electro-hydraulic actuator. **Fig. 5** Schematic diagram of Manning, Maxwell & Moore electro-hydraulic actuator. **Fig. 6** (right) Manning, Maxwell & Moore electric actuator on valve

valve, a filter, a check valve, a servo valve and a double-acting cylinder. The pump delivers hydraulic oil at 500 lb/in² to the servo valve. The servo is positioned by the force motor which, in turn, is powered by the instrument signal. Feedback and range adjustment are provided by linkages and a spring between the main cylinder shaft and the movable member in the servo valve.

The main case or housing of the mechanism serves as a reservoir for the hydraulic oil. Approximately $1\frac{1}{2}$

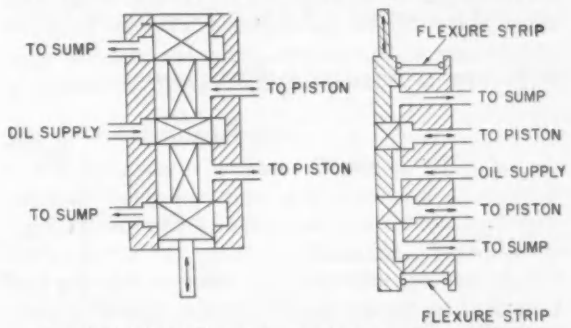


Fig. 7 (left) Spool-type hydraulic servo valve. **Fig. 8** (right) Lee & Shearer sliding-plate hydraulic servo valve

gallons is required to keep the temperature rise at about 60°F. Since the case is vented, the operator must be mounted in an upright position. The operator, without the valve body, weighs approximately 100 lb.

This model is claimed to have a maximum (stalled) thrust of 1350 lb and a no-load stroking speed of 0·4 in./sec. Maximum stroke is 4 in. Continuous power consumption is 3·8 amp at 115 volts. Sensitivity is 0·2% and maximum no-load hysteresis 0·5%. However, load sensitivity is only 2·0% for 50% rated thrust. Frequency response with $\frac{1}{2}$ in. stroke adjustment and no-load is 3 dB attenuation at 0·7 c/s with a phase lag of 90°.

The sliding spool

All of the essential components of this general design are well-known and commercially available. The servo valve (or four-way pilot valve) has been the most challenging element to designers. Hydraulic servos of the sliding spool design, Fig. 7, have been used for many

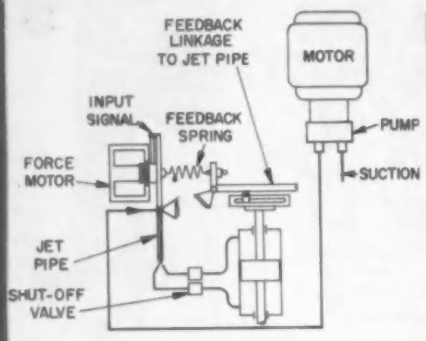


Fig. 9 (above) Electro-hydraulic actuator with jet-pipe servo

Fig. 10 (right) Electrically powered valve using jet-pipe servo

years in aircraft controls, gun pointing mechanisms and so forth, and are available as a package from several manufacturers. They have a high power gain and excellent frequency response, but are extremely sensitive to dirt particles in the hydraulic fluid and, because of the close manufacturing tolerances, their cost is prohibitive.

The design represented in Fig. 5, marked 'servo valve' and shown enlarged in Fig. 8, was developed by Lee & Shearer, at Massachusetts Institute of Technology, and is described in A.S.M.E. Paper No. 54-A-196. It is produced by drilling holes simultaneously through two metal plates that slide against each other in the final assembly. Carefully ground pegs are pressed into the holes in one plate, which results in their being exactly coaxial with the holes in the other. The movable plate is supported by two flexure strips. Adaptations of this design are being used by Manning, Maxwell & Moore (see above) and Mason-Neilan Regulator Company, Boston, Mass. (see Fig. 13). Its advantage lies in the fact that it has no extremely difficult machining tolerances.

The jet-pipe servo

Evershed and Vignoles, Ltd., London, England, and General Precision Equipment Company, Chicago, Illinois, U.S.A., offer an electric hydraulic operator utilizing a jet-pipe type of servo. This design, shown schematically in Fig. 9, and pictorially in Fig. 10, is a comparatively simple system. The force motor positions the jet-pipe or nozzle to discharge into one or the other of two adjacent receiving orifices which are connected directly to the actuator cylinder. The secret of success of this type of servo is the high degree of efficiency to which the jet-pipe principle has been developed. With oil delivered at 160 lb/in² from the jet, 90% recovery is achieved in the receiving orifices. Feedback and range adjustment are accomplished as in the Manning unit. This unit is offered with automatic shut-off valves in the oil lines to the power cylinder, which lock the valve in place upon loss of power. This is a desirable feature that could be added to any operator using a hydraulic system and a piston.

This operator is not as responsive as some on the market, and its load sensitivity is probably not as good, but its simplicity and lack of sliding parts make it de-

Fig. 11 Fisher Governor electro-hydraulic operator

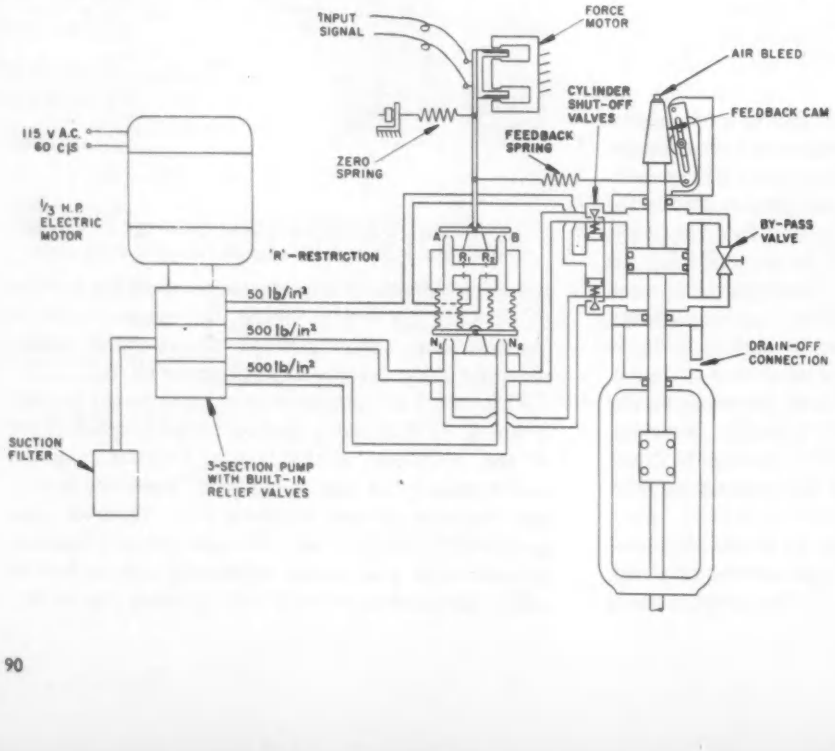
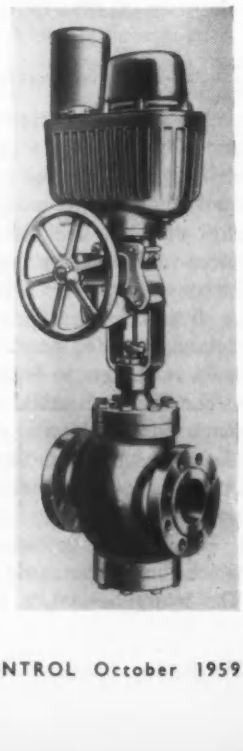


Fig. 12 Fisher Governor actuator and valve



pendable. It is offered in two basic sizes with maximum thrusts of 220 lb and 1000 lb and speeds of 0·12 in./sec and 0·50 in./sec respectively. By using larger motors and slower speed, these can be arranged to provide 500 lb and 1500 lb thrusts. More of these operators are in service than any other electrically-powered operator available.

Amplifying hydraulic servo

Figs. 11 and 12 show an operator manufactured by Fisher Governor Company, Marshalltown, Iowa, and Rochester, Kent. This unit is different in that it uses an amplifying-type hydraulic servo. It also has a three-impeller pump which delivers 50 lb/in² for the first stage of the servo and 500 lb/in² for actual operation of the cylinder. The first servo stage consists of two orifice-nozzle combinations which control the pressure in two bellows. The resulting bellows movement controls the flow from two large nozzles in the 500 lb/in² lines to the cylinder. This unit gives a thrust of 2000 lb, and a stroking speed of 0·37 in./sec. Resolution sensitivity is better than 0·05% and no-load frequency response is 1·5 c/s with 90° phase shift and 1 in. stroke adjustment.

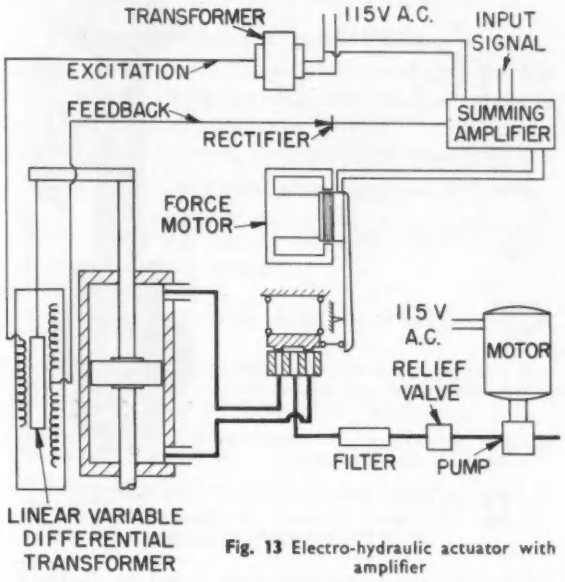


Fig. 13 Electro-hydraulic actuator with amplifier

Electric amplifiers

The operators so far discussed have used instrument signal current to power a coil which moves to operate a hydraulic servo valve. Instrument signal ranges developed by the different manufacturers have not been standardized and vary between 1 mA to 5 mA and 3000 ohm resistance, to 10 to 50 mA and 400 ohms. From these inputs, it is not possible to design a force coil with more than a few ounces of thrust. Many designers feel that this is not really adequate to provide the dependability that is a prerequisite of an industrial-quality operator

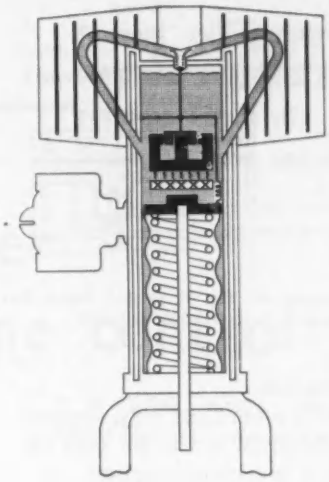


Fig. 14 Swartwout thermal actuator

Fig. 15 Swartwout thermal operator on a valve

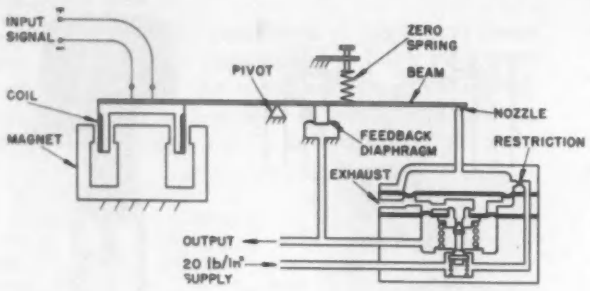
One obvious method of overcoming this weakness would be to amplify the signal electronically. By the use of such an amplified signal, several pounds of force can be obtained to operate the servo valve. An electric amplifier also makes it possible to provide electric feedback from a linear differential transformer attached to the main cylinder shaft.

A unit of this type, which is offered by Mason-Neilan Regulator Company, Norwood, Mass., is shown schematically in Fig. 13. It has accurate positioning ability and good response characteristics, but it is made in one large size only and is too complex and expensive to be considered for the average process control application.

The thermal-electric principle

The Swartwout Company, Cleveland, Ohio, has recently announced a unique control-valve actuator which operates on a thermal principle. It is shown diagrammatically in Fig. 14, and pictorially in Fig. 15. The operating principle is based on controlling the rate of heat release through a fluid (Freon) circulating through a closed chamber open only to a condenser. A bellows backed by a spring actuates the valve stem in response to changes in pressure in the Freon system.

Freon is continuously vaporized by an electric heater, which creates pressure in the closed chamber. Control action is achieved by varying the bleed rate of the Freon into the condenser through a small relief valve. The relief valve is operated by a force coil which responds to the instrument signal. When the bleed rate is decreased, the vapour pressure in the chamber increases, compressing the bellows and spring and causing a down stroke. Conversely, an increase in the bleed rate will permit the bellows to expand, producing up-stroke. Feedback is accomplished through a spring between the



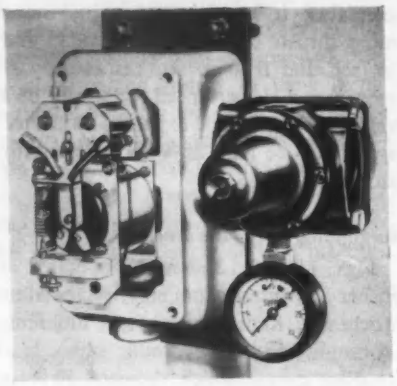


Fig. 16 Electro-pneumatic transducer. **Fig. 17** (right) Fisher Governor electro-pneumatic converter, cover removed

bellows head and the force coil.

This actuator is offered in a small size only, developing a maximum of 300 lb thrust. It has not been extensively field-tested, but it is certainly original.

Choice of operator

Of the general types of operators discussed (geared electric motor, electro-hydraulic, and thermal-electric) the electro-hydraulic has been most widely used in process plants. Its acceptance has not been general, however, and users are not wildly enthusiastic. Its performance is usually as good or better than conventional spring and diaphragm operators, and the hydraulic piston does have a stability or 'solidity' of positioning that is lacking in the resilent spring and diaphragm.

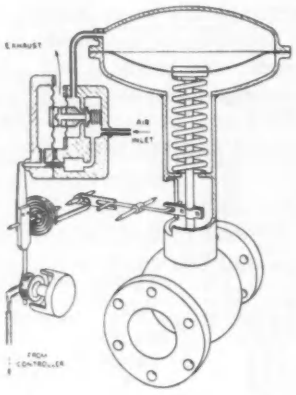
The economics of installing electrically powered valves is a debatable subject. The first cost of the electro-hydraulic actuator is from three to six times the cost of equivalent spring and diaphragm operators with pneumatic positioners. This unit cost is at least partially offset, however, by the costly air system required for pneumatic operators. In fact, some large companies that have conducted cost studies have concluded that total installed cost of electric and pneumatic operators is about equal.

When the actuators first appeared on the market, many companies bought a few for field testing, and a dozen or more process units have been completely equipped with them. A large percentage of these are in Canada, where air systems may be subject to freeze-up.

Electro-pneumatic systems

The instrument man's principal argument against the electro-hydraulic actuator is its complexity, this resulting in non-dependability and increased maintenance. This is the factor that has caused most users who have switched to electrically-powered instruments to continue to use pneumatically-powered valves. The electric signal is converted to a pneumatic signal by a transducer or convertor which may have mechanical feedback from the valve stem.

A simple electro-pneumatic transducer is shown schematically in Fig. 16. The d.c. milliamp input signal is converted to a proportional pneumatic output, usually 3 to 15 lb/in². An amplifying relay is used in the pneumatic circuit to provide high capacity. The output of this instrument can be fed directly to a control valve diaphragm or to a pneumatic valve positioner. It is adaptable to any of the currently used instrument signals. Its resolution sensitivity is less than 0·05% of the input range, and the frequency response is excellent.



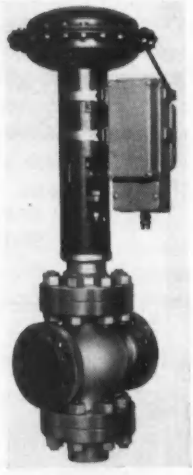


Fig. 18 (left) Electro-pneumatic valve positioner
Fig. 19 (right) Evershed & Vignoles electro-pneumatic positioner on a valve

If the transducer has the loop closed by feedback from the movement of the valve stem, it becomes a positioner also. This is shown in Fig. 18 and on a valve, in Fig. 19. It is manufactured by Evershed and Vignoles. Similar electro-pneumatic transducer positioners are manufactured by other firms.

Conclusions

Electrically-powered, throttling type control valve operators on the market so far have not been enthusiastically accepted. There is an increasing need for such a device, however, but the solution to the problem of high performance, simplicity and low cost is not an easy one. In the meantime electro-pneumatic converters are normally used.

PART 2

A steel rolling mill is a good example of plant suitable for automatic programme control. Uniselectors are finding a new use in this application.

Uniselectors enter automatic programme control

by **H. LAW, B.SC., A.M.I.MECH.E., A.M.I.E.E.**
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In Part 1, published last month, we introduced the subject with a brief review of the various classes of programme control. We then narrowed our interest to the uniselector method, discussed the choice of this technique for steel mills, and described the standard programming units that have been designed.

PROTECTION AND ALARM CIRCUITS

The standard units are so constructed that the following control, protection and indication equipment can be included for any particular scheme.

1. Indication given when a programme not wired is selected.
2. Pass number, programme number and fault indication.
3. Automatic reset after end of programme. This includes programmes shorter than the maximum.
4. Manual reset of programme at any point during the programme.
5. Mid-programme change, should this be required for, say, a cold piece.
6. Instantaneous automatic/manual changeover, together with various supervisory controls to take care of such occurrences as fish-tailing, bent pieces and false entry.
7. Manual control in the middle of a programme, reverting to automatic control for completing the rolling schedule.
8. Interlocks to prevent any uniselector breaking current on the wipers.
9. Roll wear compensation, etc.

RELIABILITY

In order to ensure that the required standard is maintained during, the manufacture of ratchet uniselectors, random samples are subjected to a minimum life test of 25 million operations; this is equivalent to carrying out a complete rolling programme or schedule on one million ingots, since the uniselector rotates once for each programme.

The similar test figure for motor-operated uniselectors is one million actions of starting and stopping. Thus, taking an average of say nine passes per programme, the output uniselector will not require serious attention until 100,000 ingots have been rolled. The input uniselectors operate much less frequently than the output uniselectors and will therefore need less attention.

Thus the equipment will need regular servicing every six months or so in order to ensure maximum reliability. In addition to this it is preferable to inspect, and possibly lubricate, the uniselectors at shorter intervals. The routine can be included in regular maintenance schedules, and, as previously mentioned, the equipment is made in easily removable units for this purpose.

It should be pointed out that uniselectors normally operate for much longer than this without trouble.

SPEED AND POSITION CONTROLS

With any type of automatic programming equipment the quantity of information handled is relatively large, and this means that, in order to keep the equipment to a reasonable size, the working power level must be small. The result of this is that relatively high-gain power amplifiers are required to control the driving motors from these small signals.

Control of speed is normally only required for the main drive itself; for most installations it is convenient to use the existing contactors and motorized rheostats, and control these through intermediate contactors and relays. This is in effect one method of obtaining the high power gain, especially where only a limited number of settings is required. This will also apply to a large extent on new mills. Where accurate speed settings are necessary (as for stand speeds on a cold tandem mill) much of the control equipment may exist already, and a small pre-amplifier only is needed.

Many manually-operated position controls (for screws, edgers, manipulators, etc.) at the moment consist of contactor-operated d.c. or a.c. motors. Where accurate positioning determined by the programming equipment is required, contactor-operated drives are usually not sufficiently accurate, and a closed-loop continuous system is necessary. An important exception to this arises in the case of automatic gauge-control schemes for cold mills, where contactor-operated a.c. motors are necessary owing to the limited space and rapid accelerations.

The output from the programming equipment is in the form of ten-digit relays, controlled by the output uniselector (see Fig. 1). For contactor-operated speed controls, therefore, the intermediate relays mentioned previously can be controlled directly.

For continuous controls, however, there are three essential elements, **1.** a position (or speed) measuring device, **2.** a unit to convert the output signal from the programmer into a form suitable for comparing with the signal from the position-measuring device, and **3.** a power amplifier to enable the error signal to control the driving motor.

MEASURING POSITION AND SPEED

For the type of continuous speed control required, for example, on most tandem mills, a simple d.c. tachogenerator of robust proportions is sufficient, but for very accurate controls a brushless tachogenerator gives more linear and drift-free results. Measurement of position requires more thought, and devices for this purpose can be divided into the following main groups.

D.C. resistance potentiometers

Robust resistance potentiometers are available for measurement of screwdown or manipulator position, and are suitable for mounting directly on the mill. The signal obtained is in the form of a voltage proportional to the measured displacement. These devices can be based on the use of a silver graphite brush running on a commutator with stainless steel segments. Alternatively a roller mechanism running on a resistance toroid can be used. In both cases encapsulation gives maximum reliability. See Fig. 5.

Due to accuracy limits in the wire itself, and to manufacturing tolerance limits, the maximum accuracy and resolution which can be obtained with reliability is in the region of 0·1%.

Digital position-measuring systems

For certain applications, such as plate-mill screwdowns, it is necessary to operate to a greater accuracy than that available from simple analogue equipment. This can be done with a coarse and vernier system, but sometimes a digital method is preferable.

Digital position-measurement equipment is available giving an accuracy of up to 1: 8000 under suitable conditions, but this accuracy can be raised by increasing the number of binary digit tracks. Units generally take one of two forms, photoelectric or mechanical-contact, and the latter can be split into two main groups. The mechanical type commonly manufactured has mainly scientific and instrument applications, and is usually based on the use of digitally coded etched discs with gold pick-up contacts. Also available, however, is a digital position measuring device sufficiently robust to mount directly on the mill itself. Three drums operate in cascade, and each drum has up to five digit tracks on its surface. Contact is made through high-grade silver graphite brushes. The conducting material on the drum is stainless steel, and this gives a very low voltage drop. The insulating portions are made from a specially developed material having a very low coefficient of friction, but which, notwithstanding this, is resistant to brush wear and plastic flow. The photoelectric and etched-disc types of position-measuring device must normally be mounted in a clean atmosphere, and where vibration is minimized. Thus Selsyns must link to the mill itself.

The signal from any of the digital measurement devices is in the form of a number of lines either energized or de-energized to form a digital pattern or number proportional to the measured position.

Variable-ratio transformers

It is possible to measure position using a sliding-contact or a rotary variable ratio transformer. However it is

GLOSSARY OF STEEL-MILL TERMS

Edgers — *Pairs of rolls with vertical axes for rolling the edges of a work-piece.*

Fish-tailing — *Splitting of the end of a piece during rolling.*

Flying micrometer — *An instrument for measuring the thickness of cold strip as it comes from the rolls. The signal is used for indication and sometimes also for controlling the gauge automatically.*

Gate or hole — *With section, rod, or bar mills the rolls are grooved to give the required shape and dimensions. There are usually a number of these 'shapes' on one set of rolls, and the piece must be positioned opposite the correct gate or hole.*

Inlet and outlet tables — *Roller tables for transporting the piece into the mill for rolling, and for taking the piece from the mill after rolling.*

Manipulator — *A pusher moving across the mill, that is, parallel to the axes of the rolls, in order to position the work-piece opposite the required gate. There are normally four manipulators, a left-hand and a right-hand unit on each side of the rolls.*

Pass — *The action of passing the piece between the rolls once, that is, making one reduction.*

Piece — *Work-piece, billet, bar, rod, section, bloom etc.*

Reversing mill — *A single-stand mill where the screwdowns reset and the mill reverses after each pass.*

Screwdown — *The mechanism which adjusts the distance between the top and bottom rolls and thus regulates the thickness of the steel.*

Single-stand mill — *A mill having one set of top and bottom rolls mounted in a single 'stand.'*

Tandem mill — *A mill having two or more sets of rolls in line so that the steel strip enters the 'roughing' stand first and then enters successively the following stands. Normally the front end of the strip enters the final set of rolls before the back end of the strip leaves the first set.*

considered that the accuracy possible from such devices is not sufficiently high for most applications; also the associated comparator and reference circuits are more complicated than with the d.c. resistance potentiometer. The main advantage of the rotary transformer is that there are no rubbing contacts.

Photocell or magnetic counters

If a pulse-rate proportional to speed is produced, it is possible to count the pulses and obtain a measure-

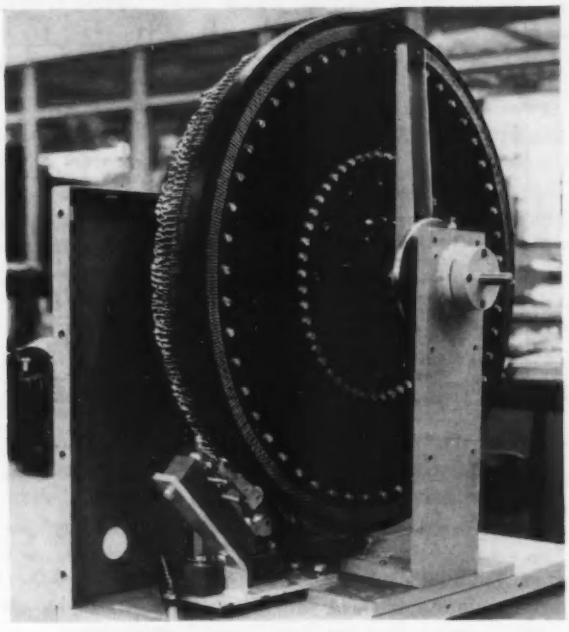


Fig. 5 Inside the d.c. resistance-type position-measuring potentiometer

ment of movement, that is, position, if the original position is known. There are many ways of obtaining these pulses, but the main difficulty with all counting systems is that relatively complicated electronic circuits are required to count the pulses and detect the direction of motion (that is, when to add and when to deduct pulses). Also, if any of the pulses are not counted due to, say, a momentary failure of the power supply, a cumulative type of undetected error is introduced.

Linear differential transformers

These consist essentially of cross-connected concentric air-cored transformers arranged so that when an iron slug is inserted into the centre of the transformer coils, an a.c. signal is obtained proportional to the position of the slug. A linearity of up to about 0·15% of the total linear travel of the slug can be obtained. The unit is suitable only for very small movements, say up to about 0·5 in. Electronic reference and comparator circuits are required since the voltage available is very small and the device cannot be loaded to any extent without losing linearity. This type of detector can be used for the measurement of strip thickness in cold mills, for it is very small and will fit into a flying micrometer.

Selsyn links

It has been shown that some of the position-measuring devices cannot be mounted directly on the mill itself, and it is necessary therefore to drive these through a Selsyn link. By increasing sufficiently the gear ratio between the mill drive and the transmitter Selsyn, the required accuracy can be obtained. However, unless cascaded Selsyns are used (and this leads to complication in the associated circuits), large errors can be introduced if one or more complete revolutions of the Selsyn are lost. This could be caused, for example, by momentary loss of the power supply, or by the receiver Selsyn pulling out of step due to a overload.

REFERENCE AND COMPARATOR CIRCUITS

The ten binary coded output lines from the programming units must be converted to a form suitable for comparison with the signal from the position-measuring device, and the method of conversion depends upon the type of detector used.

Reference circuits can be split into two main groups, analogue and digital.

Analogue

Into this group fall reference circuits associated with the d.c. resistance potentiometer, the variable ratio a.c. transformer, and the linear differential transformer.

To obtain a simple d.c. reference for the d.c. potentiometer, the scheme shown in Fig. 6 is used. Relays 1 to 10 are controlled by the ten output lines from the automatic programmer, and relay 1 corresponds to the most significant digit. The ten pairs of resistances R1 to R10 are arranged so that the resistance of R1 is double that of R2, which in turn is double that of R3, and so on. Thus it will be seen that the digital pattern set up on relays 1 to 10 is represented by the voltage at points X, Y. This voltage is proportional to the digital number. It will also be seen that the total resistance of this potentiometer remains constant independently of the reference setting. In order to compensate for d.c. voltage variations, it is usual to supply the reference and measurement potentiometers from the same source. It will be appreciated that great care must be taken to minimize the relay contact drop.

To obtain a suitable a.c. reference for variable-ratio transformers or linear differential transformer measuring devices, the ten relays must control instead ten secondary windings of a transformer, the number of turns of each winding being double that of its neighbour. Summation of the voltages from the selected windings gives a reference which can be compared with the signal proportional to position. Alternatively, using non-inductive resistances, a digital-to-analogue converter such as that described above can be used.

For some applications it is more convenient to compare currents rather than voltages.

Digital

For digital position-measuring devices it is important not only to produce a digital reference, but also to compare the two signals digitally before converting to an analogue quantity. Thus the error only must be converted to an analogue quantity for feeding into the power amplifiers.

It will be appreciated that the signal from the programmer is already in digital form. Thus, with counting systems, where digital computing circuits already exist, and where the result of a count is in digital form, it is a simple matter to subtract these two numbers using known digital techniques. As already stated, difficulties arise with polarity, but these can be overcome.

Where digital disks or drums are employed, digital computer circuits can of course again be used, but, especially with the robust drum-type digitizer, it is attractive from the point of view of reliability to exclude the use of electronics and many of the relays.

A simple circuit which is not digital in action, but which has the same effect as true digital subtraction, has been devised. The unit operates on the principle that if a digital number is converted to an analogue quantity, possibly by the method described previously, the exact digital number can be recognized from the analogue result if the conversion error is considerably less than the analogue value of the least significant digit. Thus it is possible to subtract two digital numbers by subtracting the analogue quantities derived from them, and then converting the difference back into a digital signal by means of a biased relay. If the error is large it is convenient to use the analogue signals directly so that tachometer feedback signals can be introduced, and circuits can be included to do this.

If the drum-type digitizer is used in conjunction with this scheme, an analogue signal of sufficient magnitude can be obtained directly from the brushes, and relays are reduced to a minimum. In addition, the switching frequency of these relays is low since they need not follow the digital pattern on this digitizer.

POWER AMPLIFIERS

An analogue error signal having been obtained, it is now necessary to amplify this signal in order to control the driving motor voltage. Since the positional accuracy required is usually fairly high, the power level of this signal is low, and high-gain power amplifiers are required.

For power levels of less than 0·25 mW it would probably be necessary to employ electronic or transistor amplifiers as a first stage of amplification. However with most steel-mill position controls, the minimum power level is in the order of 0·5 mW and two magnetic amplifier stages are sufficient to amplify this to a signal in the order of 500 W. For position controls with low-powered drives, say 30 to 40 h.p., it is possible to feed the main generator fields directly from this magnetic amplifier. For larger drives an intermediate exciter would be required. However, much depends also upon the speed of response desired.

Modern magnetic amplifiers using high-grade magnetic materials in toroidal form have very high-gain, linear characteristics, and are extremely reliable. Units are completely encapsulated in synthetic resin and are virtually indestructible. For installations of more than one or two kilowatts of magnetic-amplifier equipment, it is more economical to employ units designed for a 400 c/s supply and provide a 400 c/s motor alternator

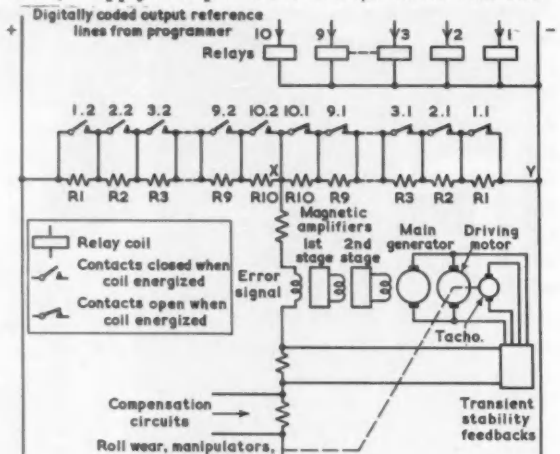


Fig. 6 Position control scheme using digital-to-analogue converter

set. Additionally, the speed of response of the 400 c/s magnetic amplifiers is much greater than that for the 50 c/s unit with a similar gain and power input.

TYPICAL INSTALLATIONS

Although this type of equipment was designed initially for steel mills, programmers using the standard units described in this article could be used to control many other types of industrial installation. The equipment would be suitable for any application where several machines are to be controlled simultaneously (in speed, position, voltage, etc.), and where successive operations in the process require a number of these groups of references given sequentially. For example the equipment could be used to control the test programme for electric motors. Each programme would represent a different motor rating, storage units would be required for the desired speed setting, torque setting etc., and each sequential setting would represent a different set of conditions during the test.

Installations based on the equipment described in this article are being put into at least two steel mills in this country, and a third completely automatic equipment is now in full operation. In order to give an overall picture of the operation of this automatic control equipment, an installation for a typical billet mill will be described. Take for example a mill rolling blooms ten or twelve inches square down to billets in the region of three to five inches square. The left- and right-hand

manipulators are controlled independently, and each has a built-in mechanism for tilting the billet when moving across the mill in either direction. There is a total of, say, seven gates. Programme storage and automatic control is provided for the screwdown, each of the two manipulators, the main drive and the inlet and outlet tables. In addition to this the mill is sequenced automatically, using photo-electric cells to detect the position of the piece.

A more detailed description of this typical installation is given below.

Programme storage

Control of the master unit is by means of six switches marked in terms of ingoing piece height, ingoing piece width, outgoing piece width (gate width) outgoing piece height (inches), outgoing height ($\frac{1}{8}$ in.) and piece temperature (hot, normal, cold). The mid-programme change facility is included so that a large number of programmes can be stored. One full programme storage unit is provided for the screwdowns, and one for each of the manipulators. In addition a vernier or fine setting unit is provided for the screwdowns, and a similar unit is provided to control the main drive speed.

Two sets of plugboards, selected by a seventh switch, are provided so that any programme not stored in the programming equipment can be set. The unit for the screwdown is in two parts: coarse setting and fine setting. The former gives settings up to 12 in. in steps of $\frac{1}{4}$ in., and the latter $\frac{1}{4}$ in. in steps of $\frac{1}{32}$ in.

Both manipulators are set up on one plugboard, and the required position is selected in terms of the corresponding gate. The left-hand manipulator is then positioned automatically to the left-hand edge of the gate, and right-hand manipulator to the right-hand edge.

Speed settings are obtained from ten rows of plugs at the bottom of the manipulator plugboard.

SCREWDOWN AND MANIPULATOR POSITION CONTROLS

D.C. resistance potentiometers using silver graphite brushes, each riding on a ring of 495 stainless steel segments, are employed to measure position on all three controls. The ten-binary-digit output lines from each of the three storage units therefore control a digital-to-analogue converter such as that shown in Fig. 6. The error signal is amplified through a 10 W and a 500 W push-pull 400 c/s magnetic amplifier, which, in each case, feeds directly the fields of the main generator. Fast dead-beat responses are obtained by feeding back signals of speed and rate of change of generator voltage to the first-stage magnetic amplifier input.

Main drive speed control

On automatic control the original foot-operated speed rheostat is replaced by a fixed resistance with contactor-selected tapping points. These contactors are controlled through auxiliary relays directly from the output lines of the storage unit for speed. Five forward and five reverse speeds are stored.

Automatic sequence control

On completion of a rolling schedule, the programmer returns to a pass 'O' setting. The screws move to the setting required for the first pass, but the manipulators open wide to receive the piece from the inlet table. A photocell detects the piece coming from the reheat furnace and starts the inlet roller table. When the piece reaches the manipulators a further photocell stops these rolls so that the piece now lies within the manipulating area. The first pass having been manually initiated, the manipulators move automatically to position the piece opposite the correct gate. Relays, detecting the presence of any voltage on either of the two manipulator magnetic amplifier outputs, prevent the main drive from running. As soon as the manipulators reach their correct position (that is, where the position error, and therefore the output from the magnetic amplifiers, is zero) the mill proceeds to run.

On completing the first pass, further photocells cause the pass-selection ratchet uniselector to move to the next position (corresponding to the second pass). This results in a new setting of screw position and a reversal in the direction of rolling. Similarly, after the second pass, pass three is selected automatically, and the main drive is restrained as before if the manipulators are moving. After the final pass, the programmer resets automatically to pass 'O' ready for the next piece.

The operator can revert at will to manual control. Alternatively he can control the main drive while still retaining the automatic setting of the screws, together with the manipulators if desired.

The speed of the mill is varied automatically to obtain optimum entry conditions for the piece, and normal protection, alarm, and interlock circuits are provided.

CONCLUSIONS

Summarizing, programming equipment will relieve the operator from the continuous strain of controlling in detail all the motions or functions on an industrial installation. This will enable him to operate much more efficiently as a supervisor, taking over and correcting where necessary. With hot reversing steel mills, for example, the operator would sometimes need to intervene should fish-tailing, false entry or bending of the piece occur.

The main advantage gained by reducing the strain on the operator is that the installation can operate at full capacity throughout a complete shift; production otherwise tends to drop off towards the end of the shift due to the slowing of the operator's reactions.

The main advantage obtained from the automatic programming equipment itself is that a more uniform product is obtained; for example, mill speed and position settings are the same for any set of conditions.

End

PART 1

A user's viewpoint on the control problems to be tackled in his industry

Instrumentation and control in the brewing industry

By **B. C. KILKENNY, M.A., B.SC., D.PHIL.**

Assistant to Technical Director, Ind Coope Ltd.

THE BREWING INDUSTRY IS OFTEN CRITICIZED AS BEING EXCEEDINGLY conservative, and in some respects this criticism is justified. But in defence of the brewer it must be said that until recently the scientific basis of his process was little understood and is even now far from being completely elucidated. Today, however, an almost complete transformation is taking place in the industry, and in the course of this, instrumentation and control are coming to the fore.

In many respects there is a long backlog to break up. In the average brewery in Great Britain (excluding bottling stores) instrumentation probably represents less than 1% of the total capital invested, compared to 5–7% in process industries generally and 10% in a new pilot brewery recently installed in the Midlands. The first stage of instrumentation is site indication and although the industry has come a long way from the days when the mash tun heat was judged with the palm of the hand, there are still many parts of the process which are often inadequately indicated.

The next step is to centralize these indications on a panel, often mistakenly called a control panel, but which, besides these indications, probably only incorporates a diagrammatic flow chart and flush-mounted starter buttons. Even this, however, is a great improvement on the state of affairs where an operator is expected to observe and maintain quality control by means of indicating instruments of all shapes and sizes scattered across the plant.

After this comes localized automatic control based on the information of the site instruments. The final step is the combination and coordination of automatic controls throughout the plant, with automatic data logging, limit alarms, etc.

Today brewing is a batch process, and if for no other reason the extent of automatic control must be limited by economic factors. And because of the process the number of indications which are necessary is also limited. In recent years, a great deal of development work has been carried out on continuous processing. Pilot continuous plants have been set up and successfully operated and continuous fermentation is in commercial operation in some breweries. It behoves the brewer, with an eye to the future, to investigate the possibilities of control instrumentation, even when working with batch processing, to see what it can offer him.

Malting

The first stage in the production of beer is the preparation of malt from barley. Although this part of the process is the one which today seems least suitable for continuous working,

GLOSSARY

Conditioning *When beer is moved after fermentation from the fermenting vessel to storage (cask or tank), a secondary fermentation may take place in the course of which the beer becomes saturated with carbon dioxide. This process is known as conditioning.*

Decoction *The mashing system used mainly by lager brewers. In this system grist is mixed with water at a comparatively low temperature. The proportion of water to grist is usually fairly high giving a very liquid mash. The temperature of this mixture is raised up to and beyond that used in the infusion system by withdrawing portions, boiling these portions, and then returning them to the remainder.*

Finings *A colloid formed by the action of sulphurous and tartaric acid on isinglass which is prepared from the swimming bladder of the sturgeon. This colloid, when added to beer, brings the yeast and protein out of suspension leaving the beer bright.*

Fob *The excessive foam of very light density formed during the movement of wort or beer due to its gas content and low surface tension.*

Germination *The initial growth of (in this context) barley corns, indicated by the formation of small rootlets.*

Grist *Ground malt plus any adjuncts, mixed ready for mashing.*

Kilning *A process whereby the growth of barley after germination is arrested, and during the course of which colour and flavour are formed and the corns dried until they are brittle.*

Infusion *The standard ale system of mashing used in this country. The grist is mixed with water at 150–160°F at the rate of approximately 72 gal water to 336 lb grist, far more concentrated than in the decoction system, and a porridge-like mass is formed.*

Liquor *All water that is used in the brewing process is called liquor—as opposed to water used for washing and cleaning.*

Malt *Barley which has been steeped, allowed to germinate and then kilned is known as malt. In effect the process involves the breaking down of the internal cellular walls in the barley corn which protect the starch, at the same time giving special colours and flavours.*

Mashing *This is the process whereby the starch inside the malt is converted to sugars and these sugars and others soluble constituents of the malt extracted from the malt. Either the decoction or infusion system may be used.*

Racking *The process of filling containers, particularly casks with beer.*

Steeping *Before germination barley is soaked with water until the moisture content is about 45%. This process is known as steeping.*

Wort *The liquid extract obtained from mashing is known as wort. Fermented wort becomes beer.*

as a batch process it offers the greatest scope for automatic control. Traditionally malting has been a manual job, carried out on open floors, and all work has been done by hand. Today more and more companies are finding that these traditional hand maltings are becoming uneconomic to operate, and are building new mechanical maltings. Normally these maltings will be directly attached to silos which house the barley straight from the farm. These silos consist of a number of vertical concrete bins, tapered at the bottom so as to be self-emptying, and down the centre of which hang thermometer ropes. These ropes hang vertically down the middle of the bin and have incorporated in them at different levels a thermometer device, which by electrical remote control can give to the barley controller an indication of the temperature of the barley at different levels. This is necessary because damp barley, straight from the farm, can by the evolution of carbon dioxide from respiration of the germ, create great heat which can be both harmful to the grain and dangerous to the whole building. Normally in a silo only those bins which are likely to hold green barley have these thermometer ropes; those into which the barley is put when it has been dried probably do not justify the expense. At the same time a method of level indication is often incorporated into the bins. These indications could control the filling of the bins, so that when one bin is full, the intake feed is automatically transferred to another bin. The discharge of the bins to the driers or steep tanks could be similarly controlled. These automatic feeds could also incorporate a weighing mechanism, and it is a simple matter to preset the amount of barley delivered to a steep. Apart from this, controls in the steeping section are not common in present day plants, as the conditions of steeping vary according to the barley used and from year to year. The time of aeration can be preset by a clock mechanism, but this receives disfavour from many circles.

All these indications and controls can be brought to a central point and an indicating panel incorporated to show the movement of the barley throughout the plant, and to show which bins are full and empty, and what is happening in the steep tanks. This merely consists of a diagrammatic panel, the respective part of which is illuminated (see Fig. 1).

Germinating

The germinating section of a modern maltings gives more scope for instrumentation and control. After the required treatment for a given year's crop of barley and a given type of malt has been decided, there is no reason why the whole germination process should not be made fully automatic. It is necessary to know the temperature, humidity and CO_2 content of the ingoing and outgoing air, and also to know the amount of air which is passing through the germinating chamber at any given time. The automatic controls are then arranged to govern the treatment of the air which is passing through; for this air must be fully saturated at a temperature which is the dew point temperature of the conditions required in the germinating chamber. The air passes through a unit containing three stages, a fresh and return air blending stage, a heating stage and a stage where the air is saturated with water chilled to the requisite temperature. The amount of hot water which is fed to the heating system, or chilled water which is fed to the cold water spray section, is controlled by an electronic thermostat operating a motorized valve, as is also the volume of recirculated air being used, as opposed to fresh air being brought in from outside.

Fig. 1 The barley control panel on the Burton silos

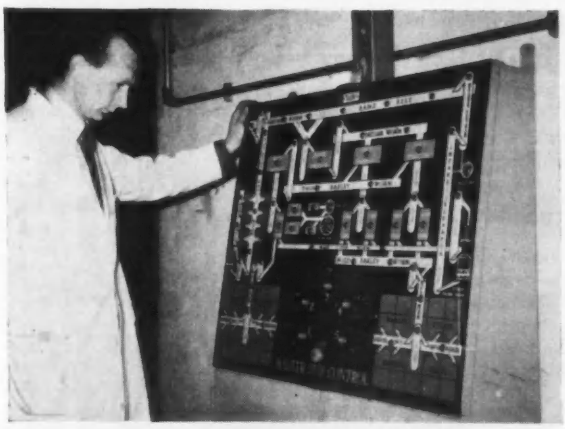


Fig. 2 Germinating box panels

At the same time, using this method, it is possible to vary the amount of carbon dioxide; for obviously, if any recirculated air is used the carbon dioxide content will tend to increase, whereas if fresh air is always used there will be no increase in concentration (see Fig. 2). Working in conjunction with such a plant will be a refrigeration unit, usually coupled to an automatic, Watford type control panel.

Kilning

The next stage in the process is that of kilning. The actual firing of the kiln can easily be made fully automatic, both with oil and with solid fuel, but the control of the times of change of temperature or quantity of air passing through the kiln is more difficult. It is customary to have a recording thermometer under the floor of the kiln, and sometimes even a recording controller placed at this point. If a definite time-temperature pattern has been established, this recording controller can be preset and fire temperature automatically altered. If the decision to change the temperature of the malt depends upon other conditions, it is customary to hand-set the temperature of the furnace.

It is also possible to examine the air leaving the kiln and record the temperature and humidity of this air. Theoretically it should be possible to control the furnace heat and the volume of air passing or being recirculated through the kiln, by a combination of preset temperature and the humidity of the outgoing air. Owing to the nature of these humidity instruments, which without a great degree of care and maintenance tend to be unreliable, such automatic kiln control has not been generally accepted.

Finally, the movement of malt throughout the germinating sections, the kilning sections and the malt storage bins, can be shown on an indicating panel, in a similar manner to the barley movements.

Such then is the picture of modern maltings. In this way quantities of something like 20,000 to 25,000 tons of malt a year can be manufactured with a labour force of about six-

Fig. 3 The malt control panel in the Saladin maltings. It shows which kilns are in use and whether the furnaces and kiln fans are switched on. The amount of malt in the silos is also shown

teen men, even less if one excludes the maintenance staff required.

Grinding

The next stage in the brewing process is the grinding of this malt and the mashing of it with water, known as liquor, at a controlled temperature, in order to obtain a wort extract. Obviously the amount of liquor present in the cold and hot storage tanks should be clearly indicated, and today there are several satisfactory ways of doing this, for example, with pneumatic gauges which work by balancing the pressure of the head of water in the tank. In the hot liquor tank the temperature should be thermostatically-controlled and indicated, and where it is necessary to boil the liquor before use as a form of liquor treatment, then a temperature recorder should be fitted as well. The photograph of Fig. 4 shows an installation where the liquor is first heated to 210°F in calorifiers, at which stage the temperature is recorded, and after which the hot liquor is stored in tanks where the temperature is indicated with edgewise thermometers.

The chemical composition of the brewing liquor is of great importance to the brewer, and while detailed analysis is a matter for the laboratory, a useful indication of the composition and of any change in composition can be given by a continuous reading conductivity meter. Such a meter is shown as part of Fig. 4.

At the same time as the water is being prepared for the mashing, the malt is being ground, and possibly mixed with adjuncts such as flaked maize or barley, to produce what is known as grist. In many breweries the amount of malt which is milled for the grist is measured by a tipping mechanism as the malt is presented to the mill. Today a more satisfactory system would be to mount the grist hopper on a load cell and record the actual weight of grist. There is no reason why a preset mechanism should not control the feed to the mills, allowing for the amount of malt which will remain in the conveyors.

Mashing

We now come to the actual mashing process itself. This may be carried out in one or the other of two ways, either by the decoction process, which is commonly used in the production of lager beer, or by the infusion process, used for the production of English, top fermented, ale beers. In the decoction process a liquid mash is used, and initially the mash is of low temperature. In order to raise this temperature, portions of the mash are removed, boiled, and then returned to the bulk, raising the temperature stepwise. When the process is complete, the whole mash is transferred to a filtering vessel, known as a lauter tun, when the wort is run off from the grain bed. In the infusion process, a far thicker mash is used, and the grist is mixed with liquor at a much higher temperature, allowed to stand, and then the extract washed through the grains in the same vessel. This vessel is known as a mash tun, and the process of washing the extract from the grains is known as sparging.

Each type of mashing presents similar problems in regard to control, but on the whole, control in the former case is easier than in the latter case. The liquid nature of the decoction mash allows reasonably accurate temperature measurement to be made and enables the temperature to be altered as desired by steam heating, using a paddle mixer to ensure uniformity. All this can be recorded. With the thicker infusion mash, accurate temperature indication is difficult, for the temperature of thermometer pockets may not be representative of the temperature of the whole. Any changes in temperature must be effected by means of the sparge liquor passing through the grains, and this control is not very accurate.

Fig. 5 shows the instrument panel in the brewhouse of a modern lager brewery. Instruments A indicate the amount of liquor in the hot liquor tanks, recorders B give a continuous record and indication of the temperature of the liquor, recorders C give a temperature record of the mashing operations in the two vessels seen in the foreground, D are steam pressure gauges and E is a thermometer indicating wort temperature in the wort receiver—a later stage in the process.

to be continued

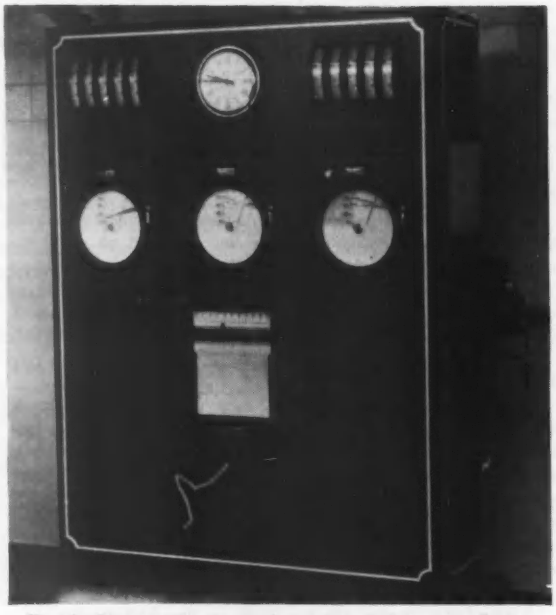
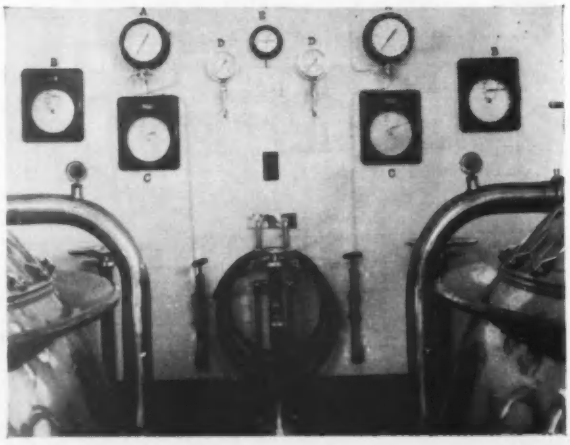


Fig. 4 The hot liquor tank room panel in the Burton brewery

Fig. 5 The instrument panel in the Alloa brewhouse



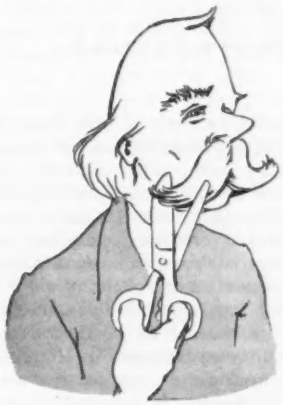
Pick-off

by 'UNCONTROLLED'

THE committee set up by the British Association last year under the chairmanship of Sir Hugh Beaver—'to report on the practicability, implications, consequences both international and domestic, and the cost of a change-over to the metric system or the decimalization of weights, measures, and coinage by the United Kingdom'—is, I gather, making good progress in its investigations. The small full-time team employed in this has been busy probing the views of industrialists, trade associations, learned societies, Government departments, local authorities, teachers' associations, and other organizations in this country. They have also been examining critically the likely export consequences of any change in units. One of the engineers in the team recently gave me some interesting figures for Britain's exports to metric and non-metric countries. Out of a total value of British exports in 1958 of £M3355, 85% went to 40 countries, each with British imports valued at more than £M20. This 85% was split in the ratio 48:37 between non-metric and metric countries, the Commonwealth and the U.S.A. of course accounting for much of the non-metric component. So despite the present world swing towards metric units the lion's share of Britain's exports is still to non-metric countries. Another complicating factor is the export competition in these countries from nations such as Germany and Switzerland, goods being specially made in 'foot-pound' sizes for export to the Commonwealth and U.S.A.

The report of the Beaver committee is expected about the end of this year, and the views in it, although not of any official standing, will undoubtedly influence Government attitude towards the thorny question of a change in British units and currency. I believe most British engineers would favour such a change in principle, but the practical obstacles are clearly formidable. In the end—owing to the importance of Britain's dollar exports—the American and Canadian attitude may well be decisive; at present American industry—and particularly Detroit—seems wedded to non-metric units, despite the decimal currency.

I HAVE been looking through the office copies of *Automatizace*, which is a 'review edited by Publishers of Technical Literature in cooperation with Czechoslovak Scientific Technical Society for Electrotechnics at Czechoslovak A of S, and with Czechoslovak Society for Spreading



Extremum Controllers

the Political and Scientific Knowledges.' Its appearance and standard of material are similar to those of the German magazine *Regelungstechnik*, except that it is badly printed on much thinner paper. The contents page and abstracts of the main articles are set out in four languages, but the quality of translation is not always high. As an example the titles for one issue are 'Czechoslovak Turning Copying Half-Automates,' 'Contemporary State of Mechanization and Automation in Consumption Industry' and 'What does it mean the extremum controllers?' (A good question to ask.) But I doubt whether many English engineers would jump at the job of translating titles like 'Dynamika impulsovych regulátoru s promennou stridou a frekuencí impulsu' (Dynamics of impulse-type controllers with variable time rate and frequency of impulses). Perhaps it is as well that CONTROL does not try to give Czech translations.

A FEW months ago I commented in *Pick-Off* on the question of keeping control room operators alert when a plant is highly automatic and they have little to do for most of the time. Many engineers are interested in this topic: it was recently debated by the S.I.T., and William Larke also referred to it in a Presidential Address to the Junior Institute of Engineers. He pointed out that an operator's alertness can be maintained in a variety of ways: 'by giving him different jobs to do; by sending him different types of signals; by inculcating into him a sense of responsibility.' Larke continued by saying that because you must provide the man anyway you will probably not fit so much automatic equipment as you might otherwise have done. This, I believe, is the wrong approach, unless the automatic equipment does not improve the operation of the plant and cannot be justified economically. Surely the right way is to try to give the operator more jobs by giving him more equipment to supervise, not by deliberately making one control panel more tricky to operate. Design engineers and plant managers should fight against creating work for the sake of it.

I DON'T know much about the why and wherefore of technical writing, and I suspect that I often fall into some well-known pitfalls. But some years ago I did read Professor Reginald Kapp's admirable monograph on 'The Presentation of Technical Information,' which should be familiar to every engineer who writes at all about his subject—and to-day that probably means 95% of engineers. Particularly good is its distinction between functional and imaginative literature, and its advocacy of metaphor. Looking at a rather uninspired book on the same subject which has been recently published made me turn to Kapp again; I was startled to find that the engineering library I borrowed it from had issued it only eleven times in the last ten years. 'The Presentation of Technical Information' ought to be better known. Paradoxically it is not physically well presented itself, although far from difficult to read. When the publishers (Constable) produce a revised edition I trust they will give it a more inviting dress.

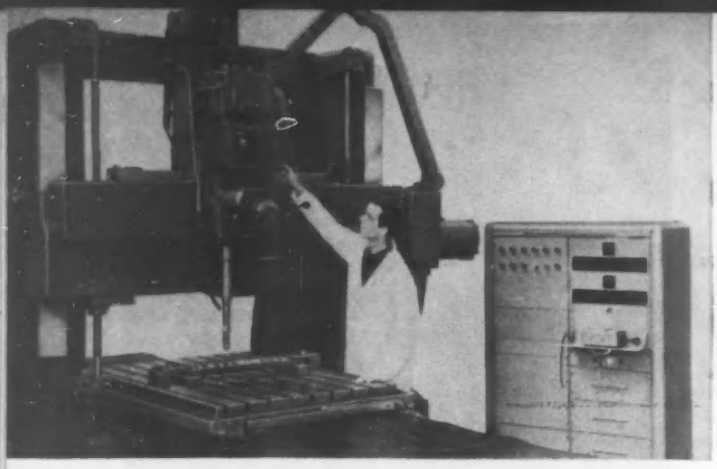


Fig. 1 Wadkin's type T.C.D.1 machine can drill holes of up to 2 in. diameter in steel. The workpiece is positioned relatively to the tool by E.M.I. Electronics' equipment, at right, which operates from either punched tape or dial settings

The British contribution to the 6th European Machine Tool Exhibition turned out to be a typical cross-section of the whole Show

British machine-tool modes in Paris

by **MICHAEL S. JOHN, M.A.(CANTAB.)**

OVER 3500 MACHINE TOOLS WERE ON display under one roof at the sixth European Machine Tool Exhibition which was held in the Centre National des Industries et des Techniques (C.N.I.T.), Paris.

The outstanding feature of the Paris Show was undoubtedly the development in standard types of machine tool, whether for turning, milling, drilling or grinding. In the control field, this general development was reflected both in the greater facilities provided for the operator to regulate the functioning of his machine, and also in the ability to fit loading and/or transfer devices without any major alteration to the general control system of the standard machine.

A simple example of the former kind concerns control pendants. The demand from designers of copying machines has been for a compact control panel on which all the functions of the machine could be conveniently pre-set before initiating the automatic cycle. Control panels of a kind have long been available, but a specific demand of this type from machine tool designers has had the effect of calling forth control units of unprecedented flexibility and reliability. Even a cursory glance showed that it is not yet the rule for standard machines, such as centre lathes or milling machines, to have a pendant switch from which the operator can conveniently control the switching on and off of the motor or motors driving his machine. However, a closer examination indicated that an increasing number of standard machines are so fitted, and that many are even provided with the means to pre-set speeds and feeds by turning the appropriate knobs. The facility is, of course, particularly valuable on larger machines and it was on this type of equipment that really sophisticated forms of control pendant were normally to be found.

The next logical development is for standard machines to be programmed to change speeds and feeds automatically as successive tools come into position. Fig. 5 shows a Herbert 2D capstan lathe fitted with a plug-board to relieve the operator of the need to change speeds and feeds when indexing the turret. Even more important than the actual time saved in engaging the new speeds and feeds, is the fact that the operator is never tempted to run with inefficient cutting conditions because he cannot be bothered to move his working position sufficiently to effect the change. When the change is taken care of automatically the operator can fall into a simple working rhythm which would otherwise be impracticable.

The example illustrated in Fig. 5 uses a plug-board which can be removed when a batch is completed and stored until another batch is required. The plug-board for the next batch is then merely withdrawn from stores by the setter as an integral part of the tooling. Almost equally popular was the insertion of appropriate pegs in a punched roll of metal or plastic.

All this improvement in control has only been possible because of the real but unspectacular developments in electro-hydraulic mechanisms. One designer of machine tools remarked that such mechanisms were now being produced 'with our needs primarily in mind.' Another feature noted with approval by this designer was the increasing availability of fittings for use with nylon and other non-metallic tubing.

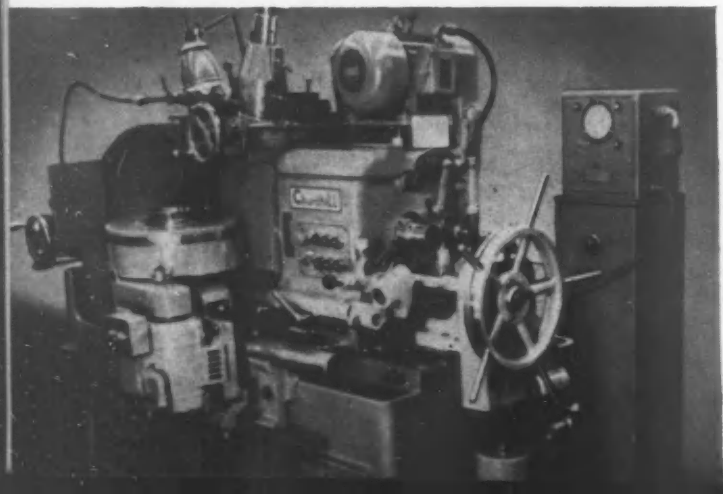


Fig. 2 Sigma Instruments' pneumatic - electric controller of this Churchill centreless grinder compensates for wheel wear and shuts down when necessary

Feeding workpieces to standard machines

There is now no standard type of machine which cannot be loaded and unloaded by the addition of a simple

attachment. Fig. 4 illustrates a typical hopper-fed gear generator. Although not apparent at first sight, the fact that such attachments can be fitted without major alterations stems largely from recent improvement in control gear. Automatic feeding is only practicable if any mishap can be sensed and the machine shut down before damage occurs. The need for a negative feedback on standard machines was not apparent so long as an operator was present to initiate the necessary corrective action. Only when more sophisticated forms of control were introduced was it practicable to introduce an automatic cycle on a standard basic machine. As so often happens, advances in one field have made possible developments in a different but related field.

Negative feedback

Fig. 2 shows how negative feedback can be used to make a machine tool largely independent of the operator, once the initial set-up has been completed. The machine illustrated is equipped for

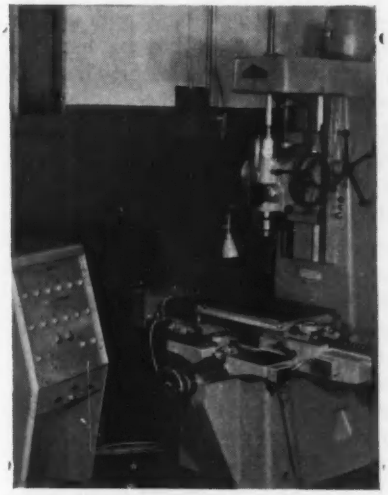


Fig. 3 Newall Engineering's Spacematic 1520 jig boring and milling machine with Airmec 'Autoset' for automatic setting of table co-ordinates

the centreless grinding of large quantities of identical parts by the throughfeed method. The components are fed between the grinding and control wheels from the bowl feeder at the left. Movement of the grinding wheel to compensate for wheel wear is effected automatically under the control of the 'Sigma' pneumatic-electric controller on the right of the picture. The gauging assembly comprises an air gauging unit attached to the exit side of the workblade. On leaving the grinding zone, the components pass through the gauging unit where their size is sensed by air jets impinging on the ground diameter. There is no direct mechanical contact with the workpiece.

As wear occurs and the tolerances on components move towards the upper limit, the signal from the gauging unit acts through the controller to provide the appropriate intermittent feed motion to the grinding wheel. Should a temperature change or other contingency cause the size of the workpiece to fall below the bottom limit, arrangements are made to halt the flow of workpieces into the machine and signal the trouble by a warning light or alarm.

Automatic positioning

Many machine tools were provided with forms of control for the automatic location of the workpiece relative to the tool. Fig. 3 shows a jig borer under the control of a system which operates by measuring precisely the total angular rotation of the hardened and ground leadscrews driving the table. This system does not use electronic valves and is cheap and robust, operation being effected by means of low voltage, direct current switching circuits based on Post Office relays. The range of movement of the table under automatic control is 15¼ in. by 10¼ in. with an overall accuracy of ± 0·0005 in. although higher accuracy can be achieved over shorter distances. Repeatability is within about 0·00015 in.

As with most automatic positioning systems, table position can be determined by setting the dimensions on dials or punching them in tape (or cards).

Fig. 1 depicts a tape-controlled drilling machine working under fully electronic control. The linear and rotary 'Inductosyn' elements used provide a very high degree of flexibility and accuracy (*1*).

The Ferranti system (*2*) controlled a Kearney and Trecker milling machine. Although still based on the use of the moiré fringe interference pattern generated by the relative movement of two diffraction gratings, this system has been so improved as to be almost a new development (*3*). The control units have been miniaturized by the use of transistors, and a reflexion principle is now employed which permits the substitution of stainless steel for glass in the optical system.

A similar moiré fringe system has been applied with great success to a measuring machine which presents inspectors with a direct digital display of the coordinate position of holes and profiles relative to a pre-determined datum.

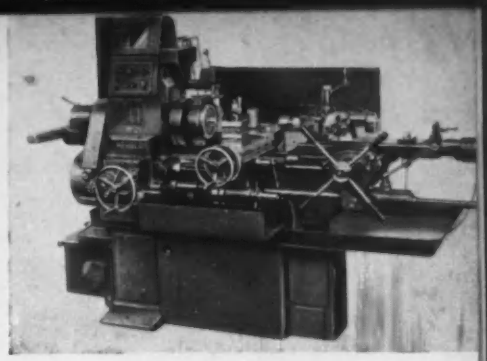


Fig. 5 Spindle speeds, stopping, starting and reversing are pre-programmed on this Alfred Herbert 2D capstan lathe

Contactless electrical control gear

The types of measuring system discussed above have led naturally to more sophisticated forms of electrical control gear for machine tools. Of particular interest in this respect is the Bi-Stat System by Brookhirst Igranic Ltd. As its name implies, this is a logic control which dispenses with contactors and other 'contact-using' devices in favour of a circuit built up from an appropriate selection of static elements such as transducers and high-speed magnetic amplifiers.

The above survey of developments in control techniques at Paris has been based largely on the British exhibits. This concentration on the exhibits of one country was made for two reasons. Firstly, of all Continental countries Britain has pioneered the use of numerical control systems for machine tools. The lead of British firms, although inevitably narrowed as more companies enter the field, was still apparent at Paris. Even among the less dramatic developments, clear examples could invariably be found from amongst the products of the 63 British exhibitors. As a result, this compact group provided a clear and representative sample of the overall developments stretching over the 750,000 square feet.

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2. Williamson, D. T. N.: 'Computer Control of Machine Tools,' CONTROL; Parts 1 and 2, 1958, *1* (July), p. 19; 1958, *1* (August), p. 70
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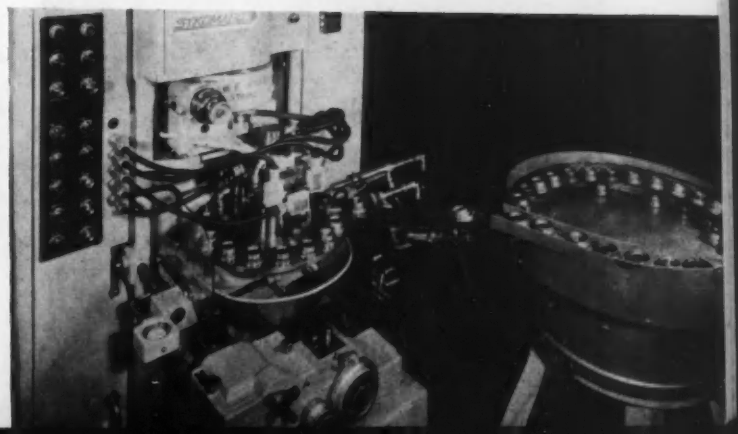


Fig. 4 The operator of this hopper-fed Sykomatic gear generator, by W. E. Sykes, need only top up the hopper and remove completed components

Fig. 1 S.R.N.1 Hovercraft

The image of last month's big show at Farnborough may well be a little blurred for the average visitor. This review brings it into focus

From low hover to high Mach

by **R. J. A. PAUL,** B.SC.(ENG.), A.M.I.MECH.E., A.M.I.E.E.
College of Aeronautics, Cranfield

THERE WAS A GREAT DEAL TO INTEREST THE CONTROL engineer at this year's S.B.A.C. show* Interests vary, and selection is bound to be a personal matter. This review is an account of what seemed to me to be the more significant things at the display.

THE FLIGHT FROM FIXED WINGS

Saunders Roe S.R.N.1

The highlight of the flying display was perhaps the demonstration of the Saunders Roe S.R.N.1. This machine is supported on a pneumatic cushion. An annular jet discharges air inwards from the craft to the ground, and the curtain so produced contains the cushion air. It is the force required to bend the curtain outwards that dictates the magnitude of the cushion pressure. The cushion is carried along with the craft, and any losses are replenished from the air curtain. The craft possesses inherent vertical stability, since a loss in height results in an increased cushion pressure, and a rise in height above the design figure results in a loss in lift. The craft appears to have inherent lateral stability, but why is not obvious. There may be difficulties with ocean-going vessels, and some form of auto-stabilization and height control may be necessary.

Fig. 2 Air nozzle on nose of Short S.C.1. Flow is regulated by a shutter which is operated by the aircraft's autostabilizer through a mechanical link

The Short S.C.1

The S.C.1 is a small delta-wing aircraft with no tailplane. Four of its five RB 108 engines are mounted vertically for lift, and the fifth exhausts horizontally at the tail to give thrust for forward flight.

This is an interesting aircraft from the control point of view. The problem of stability in the hovering case is similar to that of balancing a plate on a pencil. Since aerodynamic control is impossible when the machine is hovering, stability is achieved by providing controllable jets of air at the wing tips, nose and tail. The air to feed the nozzles is bled from the engine compressors, and regulated by movable shutters inside the nozzles. An autostabilizer relieves the pilot of the task of maintaining stability; he can therefore devote his attention to control of the mean altitude and to navigation. The autostabilizer also provides valuable assistance during transition from hovering to forward flight, for there is a period during which stability is achieved partly aerodynamically and partly with the aid of the jet nozzles. For this reason the autostabilizing system is linked to the control surfaces as well as to the nozzle shutters. Its simultaneous application to both constitutes full servo control, as distinct from manual and nozzle control. The pilot can select any of these operating conditions by means of a clutch mechanism. The pilot manœuvres the aircraft by means of the control column, and its movements are electrically signalled to the autostabilizer amplifier. There they are added in correct proportions to stabilizing signals produced by gyroscopes measuring the rate of angular movement of the aircraft. The autostabilizer amplifier feeds electrohydraulic servo motors which operate the control surfaces and nozzle controls. To improve reliability both pitch- and yaw-control channels are triplicated, with the exception of the mechanical input and output compon-

**A preview appeared on p. 82 ff in last month's issue of* CONTROL.

ents. The next stage in development will be transition from hovering to forward flight.

V.T.O.L. Aircraft Control Fan

Boulton Paul Aircraft Ltd., in collaboration with the Ministry of Supply, have investigated various types of fans for lifting and controlling vertical take-off and landing aircraft. The unit exhibited was developed to investigate the performance of a small ducted fan operated by cold air drawn straight from the compressor of the propelling engine. It also provides a means for assessing the control problems associated with longitudinal and lateral control and stability.

An exploded view is shown in Fig. 3. It consists essentially of a single-stage fan driven by a turbine mounted on the tips of the blades of the fan rotor. Air is supplied to opposite sides of the main casing, and led to two annular ports each subtending an arc of 74·5°. The air is then expanded through turbine nozzles. Flow is controlled by opening and closing the nozzles with cut-outs in the throttle ring. The latter is turned by an electrically actuated rack-and-pinion quadrant.

The supersonic nozzles accelerate the air before exhausting through the (impulse) turbine. The rotor of the axial fan is the only continually moving part of the system. Air is induced through the fan duct by the rotor, and the angle at which the incoming air meets the rotor blades is controlled by variable-incidence guide vanes. The latter are interconnected within the hub of the fan and controlled by a master vane, the outer end of which is linked to the throttle-ring mechanism. Thus the inlet guide vanes operate in unison with the throttle ring, and in this way the power supply is varied in accordance with the work done by the fan. This arrangement provides rapid thrust change without alteration in rotor speed, so the undesirable inertia time-lag of the rotor is not introduced into the control system.

GUIDED WEAPONS

Shown for the first time was the infra-red head of the passive-homing de Havilland Firestreak, with its guidance system displayed. The head is gimbal-mounted to move in pitch and yaw, and is enclosed in a nose comprising eight optically flat glass panels. The radiation from the target is collected by a forward-facing concave mirror. This mirror is fitted around the base of a central tube on the movable head, and focuses the rays on to a rearward-facing mirror. The latter reflects the infra-red radiation on to a heat-sensitive cell mounted inside the central tube. Two rings of optical windows, which were painted over for secrecy, were situated behind the guidance head in the exhibit. These are used for proximity fusing.

A two-stage version of the Saunders Roe Black Knight was displayed on its launching platform. Nearby was the nose section of an experimental head, that, detached from the main body of a single-stage Black Knight in the ascent, had re-entered the atmosphere from an altitude exceeding 500 miles at a velocity of about 12,000 ft/sec. It was heavily instrumented to provide data on re-entry heating and dynamic behaviour. The Black Knight rocket engine, the Gamma 2, was also shown. This engine uses kerosene fuel and highly concentrated hydrogen-peroxide oxidant. Four combustion chambers, each equipped with its own fuel and oxidant turbo-pumps, are swivelled on trunnions by hydraulic servomotors to control the vehicle in pitch, yaw and roll.

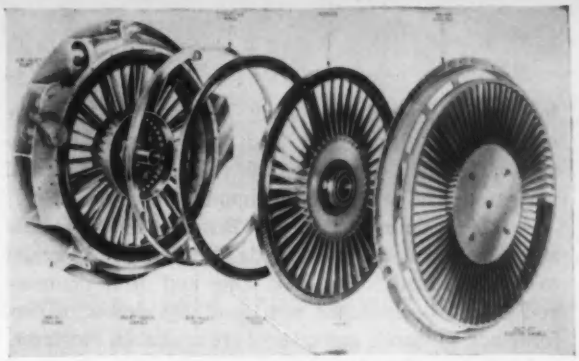
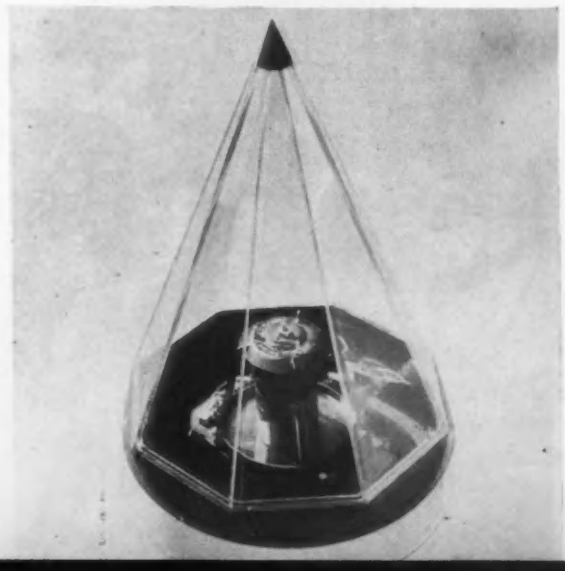


Fig. 3 Exploded view of Boulton Paul control fan. At the extreme left is the main casing, with tangential air inlets and radial inlet guide vanes. To the right of this are, respectively, the throttle ring, nozzle ring, rotor and rear casing

Models of the A. V. Roe supersonic stand-off bomb, Blue Steel, were shown for the first time. The airframe is a tail-first delta, and control is on the 'twist and steer' principle. Guidance is based on an automatic pilot and inertial navigator. V-bombers can launch this weapon at a safe distance from defence interceptor missiles etc. No details of the inertial navigator have been released. It is apparent, however, that to achieve high accuracy, precision components and accurate computation are required. For example, gyroscope wander rates of much less than one degree per hour and accelerometer errors of the order of 0·1% can result in computational errors of several thousand feet at target. According to a recent announcement, an accelerometer has been developed weighing about 1·5 lb and possessing a sensitivity better than a hundred thousandth of gravity. The basic features of the inertial navigator for a stand-off bomb were displayed by Elliott Bros. During initial flight to the target, the inertial navigator — monitored

Fig. 4 Homing head of the Firestreak



by other airborne equipment — is used to improve navigation of the aircraft. Just before the bomb is released, final position information is fed to the inertial navigator. The latter then computes the course.

A 1/5 scale model of the British ballistic missile Blue Streak was exhibited by de Havillands. The actual missile is stated to be 70 ft long and 10 ft diameter and should be launched next year. No details of performance, guidance and control are available. However, it is obvious that for control in space some form of jet control would be used. This should prove to be an interesting problem.

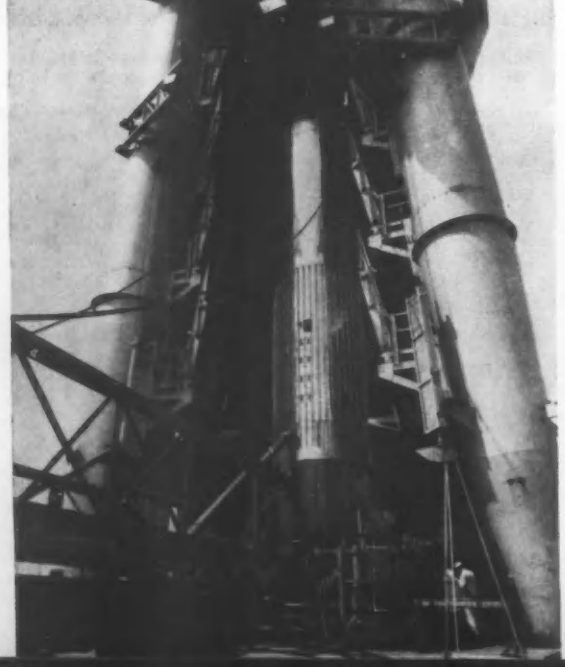
Visual Command Guidance Systems

Making its first appearance at Farnborough on the Ministry of Supply stand was the anti-tank weapon Malkara, developed in Australia. The method of control is line-of-sight command guidance, with the signals transmitted by wire link. Launched from a mobile platform, it is stated to have a range of about two miles. The missile is 77 inches long, has a wing span of 34 inches, and weighs 208 lb. It has been adopted as the first anti-tank weapon for the British Army following extensive trials at Kircudbright, Scotland.

COMPUTERS

Short's exhibited for the first time a quarter-scale model of their new precision computer, which has many novel features. With the components housed in a temperature-controlled oven, the linear component accuracy is 0·01%. An important design feature is the completely flexible removable patch panel on which connexions are made by a combination of single-pin plugs and single-patch cords, none of which need cross. It is claimed that no other computer of equivalent capacity offers such a simplified system. The capacity of the basic unit includes 112 amplifiers, 366 passive

Fig. 5 Blue Streak missile in testing tower at Hatfield



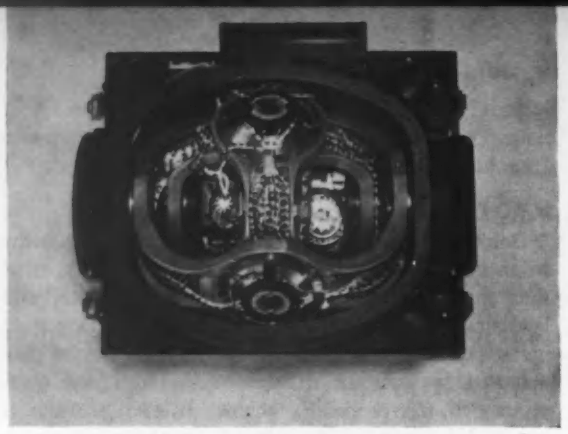


Fig. 6 Gyro and gimbal assembly of Minneapolis-Honeywell inertial platform

elements and nine non-linear units. Various combinations of units may be used, however, and extension units may be added.

Potentiometers are zero-set to better than 0·01%, using a digital voltmeter as an error detector. The measurement section comprises a six-channel recorder, oscilloscope, voltmeters, and a digital voltmeter and printer. A selecting system is used to connect any amplifier to any of the measurement channels and to choose and set the potentiometer values required. A comprehensive automatic problem-check facility is a good feature of the design. Further development may include punched tape programming and patching.

STABILIZED PLATFORMS

English Electric Ltd. exhibited for the first time a miniature stabilized platform which is the heart of inertial guidance systems for missiles, aircraft and ships. The platform, weighing only 27 lb, was mounted on a rocking table simulating a manœuvring aircraft. Used for inertial navigation, the accelerometers on the stabilized platform give outputs of acceleration, velocity and distance covered, along three mutually perpendicular axes. These are kept in constant alignment by the gyroscopes. Unaided inertial navigation may be used for about fifteen minutes, but, for longer flights, monitoring by other navigational aids such as Doppler is necessary. Three M.I.G.—GG 49 miniature integrating gyroscopes, fully floated, developed by Minneapolis-Honeywell are used. The three GG 56 accelerometers are of the pendulous current-balance type. All the associated electronics are contained in a separate pack and weigh about 26 lb.

S. G. Brown Ltd. exhibited their Mark II master reference gyroscope which will be flight-tested this year. The wander rate is about 1°/h under operational conditions. This is a development of the Mark I version, which consists of two gyroscopes mounted on a servo-operated platform providing a vertical and azimuthal reference. The new unit has been transistorized, and the weight including servo amplifiers is 25 lb.

A twin-gyroscope stabilized platform was exhibited by Sperry employing two Rotorace gyroscopes for which the wander rate is claimed to be about 0·5°/h.

Fig. 1 Aerial system of Decca Radar's nodding heightfinder type HF.200

CONTROL IN ACTION

Servo techniques yield improved performance in Decca Radar heightfinding aerial

Hydraulic control of radar heightfinder

WELL PROVEN HYDRAULIC TECHNIQUES ARE prominent in the aerial system used in Decca Radar's type-HF.200, a high-power nodding heightfinder specially developed to operate with the latest long range, high cover, surveillance (or plan) radars. It illustrates an interesting application of hydraulic practice in overcoming earlier drawbacks in this type of radar as well as in achieving new design aims in a specialized equipment where precision and reliability are essential.

Radar heightfinder's role

The servo systems in the type HF.200 are directly related to the functions it performs as part of a complete civil or military radar system giving data in three dimensions. The surveillance radars in present-day use furnish only range and bearing information, which is insufficient to pin-point a target's position in space. A separate radar is therefore necessary to supply height information of at least comparable accuracy. The most common form of heightfinding radar is one with a very narrow vertical beam which can be quickly slewed on to the bearing where the plan radar has detected a target. On this bearing the beam nods (or nutates) in the vertical plane, thus illuminating the target. From the value of slant range and the sine of the corresponding angle of aerial elevation, height is automatically extracted.

A general view of the HF.200 aerial is shown in Fig. 1. The azication servo system is contained in a unit at the base of the tripod, and the nutation servo unit is mounted at the rear of the horizontal yoke. This, with two support arms, forms a cradle in which the 35 ft reflector framework is pivoted.

The azication operation

Causing the heightfinder aerial to slew on to an azimuth bearing designated by the plan radar operator is known as 'azication,' and this is accomplished in the HF.200 as shown in Fig. 2. The operator of a p.p.i. unit displaying the plan radar signals has under his control an 'interscan' line which he can position in azimuth or length (range) at will. Turning the azication knob to bring the line to any bearing, say 090° as in Fig 2, will, via the azimuth servo system, cause the aerial to swing on to this bearing. The target echo will then appear on the associated height range display on which angle markers indicating the angle of elevation also appear.

Essentials of the servo systems

Clearly, apart from the purely radar characteristics such as range and height accuracy, the most important quality of a heightfinder is its target capacity in terms of height readings per minute on targets which may subtend angles of between 0° and, say, 33°. For the HF.200, height readings can be obtained on 15 targets/min on a sequential basis, and 8 targets/min on a priority basis. To achieve this rate a system having fast positive response, and a nutation drive capable of rapid nodding over a much wider angle than that employed in earlier heightfinders, was necessary. The use of hydraulics for these systems permitted recourse to be had to established techniques, as, for example, those used in the design of high-speed and highly accurate gun turrets. It also offered adaptability for special-purpose operation.

Azimuth servo unit

Fig. 3 is a block schematic of the azimuth servo. The controlling element is a synchro transmitter operated by the azication knob shown in Fig. 2. Any rotation of this synchro is translated into corresponding rotation of the aerial by means of a servo loop acting on the hydraulic system. The control synchro is connected to the remote windings of a hunter magslip, whose local windings are energized by a resetting magslip transmitter mechanically driven by the rotation of the aerial. The magslip hunter detects the difference between the two inputs, and should an error signal be generated due to a movement of the azication control, the aerial is turned to the desired bearing.

The error signal causes the hunter rotor to deflect, and this operates a sensitive valve in the hydraulic servo amplifier. The output of this amplifier operates the control lever of a variable-delivery oil pump driven by a 10 h.p. three-phase induction motor. A hydraulic motor in the aerial pedestal is associated with the oil pump, and the whole assembly forms an infinitely variable forward or reverse gearbox. The hydraulic motor is geared to the aerial turntable and it is also coupled to the resetting magslip;

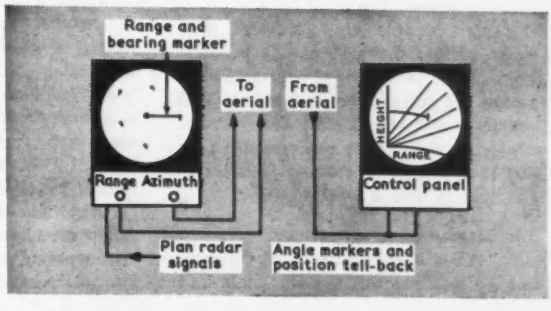


Fig. 2 The 'azication' operator slews the heightfinder aerial by varying the range and azimuth marker controls of the plan radar to identify the wanted target

thus the aerial will be rotated until the error signal detected by the hunter is zero. The gearing provides speeds of 6–0–6 rev/min.

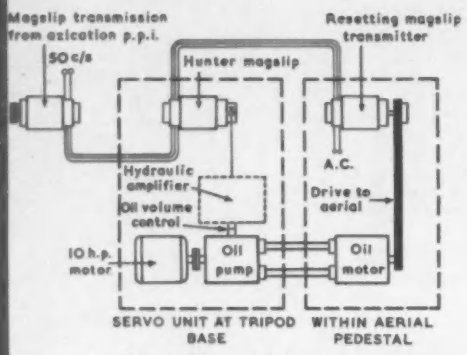


Fig. 3 The aerial-slewing servo system is controlled by a synchro operated from the azication position. See Fig. 2

The hydraulic amplifier is extremely sensitive and gives a maximum output torque of 40 lb. ft from an input from the hunter magslip of less than 1/10 oz. in. The response time of the amplifier can be altered by varying the size of an oil orifice within the amplifier, but, for normal duty, a 'zero-to-full' output response time of 0·9 sec has been selected. This produces the minimum acceleration and deceleration forces in the servo gearing and structure, and results in a single overshoot action.

The system is a 'true position device.' The acceleration, deceleration and rotational speed are independent of the velocity of the input motion given to the azication synchro, and correspond to the limiting structural forces permitted by the design.

The servo circuit consists of a hydraulic amplifier, as the first servo element, in series with a variable-speed hydraulic pump and motor as the second. The first element incorporates its own hydraulic feedback system, and there is feedback across both elements as a whole via the resetting transmitter. This gives the overall system a second-order transfer function which is fundamentally stable and a state of self-oscillation cannot be induced by variations of components in the servo loop.

The system is self-locking and when at rest cannot be disturbed by wind or other external forces.

Its components are assembled in a single unit at the base of the pedestal. Lubrication is provided by a ¼ h.p. motor, oil pump, filter and piping. This system is interlocked with the electrical supply, is of the fully re-circulating type and incorporates lubricating 'anti-scuff' additives to reduce wear and tear.

The nutation servo system

Fig. 4 is a block schematic of the nutation or nodding servo. Both angle and rate of nutation are direct functions of the movement of a hydraulic ram, which is fixed to the back of the aerial reflector.

Oil pressure is provided by a 7½ h.p. totally enclosed induction motor driving a pump capable of a constant delivery of 6600 in³/min at a working pressure of 300 lb/in². Oil is drawn into the pump from a reservoir, fitted with filters and a thermostatically controlled immersion heater, which maintains the oil at constant temperature. From the pump the oil flows via a relief valve to a solenoid-controlled pilot-operated changeover switch actuated by the electrical control system. According to the position of the changeover valve, oil flows via two check valves to the ram, producing an upward or downward stroke. The oil displaced from the ram flows on its return path through a flow control valve whose setting determines the nutation rate. The check valves close in the event of electrical failure, and thus lock the ram to prevent further movement.

Because of the curvature of the earth, even high-flying targets at long range subtend a relatively small angle, and it is therefore wasteful to employ the full vertical sweep of the reflector when dealing with such targets. Accordingly, the system has been designed so that the angle of nutation is automatically reduced for long-range targets. The nodding rate for the full nutation angle is 20 sweeps/min but this can be increased to 50 sweeps/min for an 8° nutation angle. This facility is brought into operation by adjusting the length of the range and bearing marker line on the azication p.p.i. (Fig. 2) to coincide with the target, thus defining its range. As the range is adjusted, the d.c. signals, which are a function of range, are fed to the nutation-angle controller in the nutation servo unit. Here they oppose signals received from the aerial resolver which have been rectified. When the aerial resolver circuit output exceeds the incoming range signal, a relay closes to provide actuating current for the solenoid reversing mechanism of the oil changeover valve, thus causing the reflector to reverse its motion and commence its downward stroke.

By this means the nutation angle may be varied, and this variation is arranged to follow a pre-determined law whereby the nutation angle is reduced for long-range targets and increases as the range shortens.

The tubular yoke which forms the main support for the rotating part of the aerial also serves as the oil reservoir and is fitted with an oil filter and thermostat control for maintaining constant oil temperature. The remaining components of the nutation hydraulic system are grouped in a separate container mounted on the top of the yoke. This container is connected to the ram by two pipes which complete the oil circuit of the ram. The ram itself has a shock absorbing buffer incorporated at each end of the stroke, to prevent damage if electrical failure interrupts the changeover action.

Benefits derived from servo systems

Both servo systems have successfully undergone trials to measure response times, accelerations and decelerations, the long-term endurance under both static and dynamic conditions, and overall system performance.

The drawbacks from which earlier heightfinders suffered, insofar as their slewing and nutation mechanisms were concerned, were that they had a fixed non-linear sweep over a limited vertical angle, insufficient mechanical versatility and overall accuracy, and heavy wear and tear on moving parts. These have been overcome by the hydraulic methods adopted. The nutation system gives a wide variable sweep, and the ram imparts a constant angular velocity over the greater part of the sweep, giving a constant number of pulses per beamwidth—unlike earlier crank systems. Furthermore it has no gearing.

The slewing motion is smooth, and optimum damping is introduced to avoid any oscillation about the desired azimuth and to give a single overshoot which is well within the azimuth beamwidth of the radar. Because acceleration, deceleration and rotational speed are independent of the velocity of the input motion, rough handling of the azication control cannot be reflected in damaging motions of the aerial assembly.

The HF.200 servo system can be adapted in various ways as, for example, to azicate between two bearings at full speed with dwell on two targets.

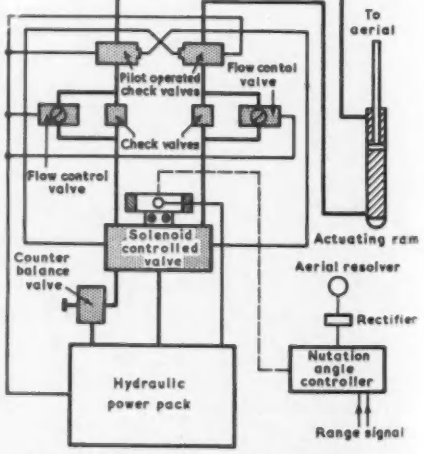


Fig. 4 The nutation, or aerial nodding, system. The angle and the rate of nutation are both direct functions of the movement of a hydraulic ram fixed to the back of the aerial reflector

Electrically governed magnetic-powder clutches provide automatic gear changing

Autocontrolled transmission in Hillman Minx

THE ROOTES GROUP'S NEW HILLMAN Minx motor car has fully automatic transmission by Smiths Motor Accessories, an electro-mechanical system of pronounced control engineering interest. The system is based on the Smiths magnetic-particle coupling, a form of transmission which employs metallic powder in an annular space between the input and output rotating members. A magnetic flux 'freezes' the powder to give the effect of a solid drive.

Such a coupling can be used as a clutch to accelerate a vehicle from rest, by energizing its flux coil from the vehicle's generator. As the throttle is opened, engine and generator speed increase, as does generator voltage across the flux coil. The torque transmitted is almost directly proportional to the current supplied by the generator so that smooth take-up should result.

Two couplings are used in conjunction with a constant mesh layshaft gearbox in the transmission system for the Minx. The schematic layout is given in Fig. 1.

One magnetic powder coupling gives direct drive via a shaft which passes straight through the gearbox and forms the final output member. The other coupling gives the indirect gear. First gear output is transmitted to the final output shaft through a free wheel, while second gear output is transmitted to the same final output shaft by an electrically engaged set of dogs.

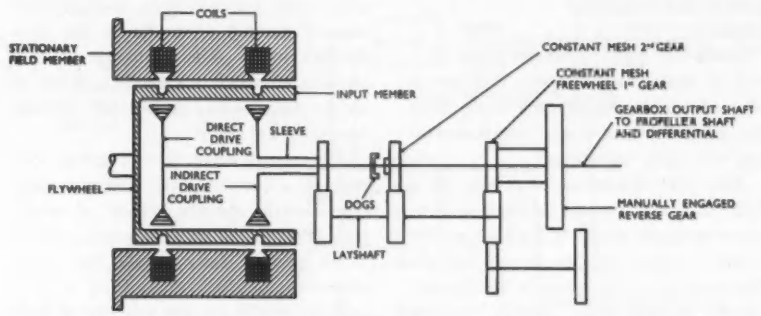


Fig. 1 Schematic layout of the Smiths three-speed automatic transmission system

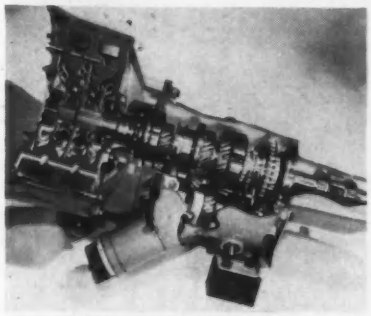


Fig. 2 The system cut away to show the two magnetic-particle couplings and the gearing

Gear changes can be made without interrupting the engine torque, by a straight switching of the magnetic powder couplings on the second-to-third change, or by engaging the second gear dogs when these are exactly at synchronous speed during the changes from third to second and first to second.

Control system

The automatic transmission incorporates a control system which relieves a driver of the burden of deciding when to change gear. In theory any driver should be able to obtain maximum performance from the vehicle and although this is true to a great extent the skilled driver can still influence the transmission. This results from the fact that the integration of vehicle speed and throttle position is fully progressive.

The governor, which is sensitive to both road speed and accelerator pedal position, is based on the use of a permanent magnet eddy current coupling, of drag cup type, as the speed-sensitive element. This is driven by a flexible shaft from the rear of the gearbox mainshaft, and rotates at a speed proportional to road speed. The governor incorporates electrical contacts which make and break to provide signals controlling the transmission.

The underlying principle of the system is shown in Fig. 3. These contacts are arranged to move through two separate arcs so that, when the car is stationary, a contact whose position depends on road speed makes with another contact to demand first gear. As the throttle is opened, the road speed contact moves clockwise but the circuit remains made because the second contact also moves clockwise under control of the throttle. Ultimately, however, road speed increases to such an extent that contact is broken and second gear is selected. Further increase in vehicle speed will bring together the road-speed contact with a third contact so that another circuit is made and top gear is engaged. It follows that the position of the throttle has considerable control over the speeds at which gear shifting occurs—the larger the throttle opening, the higher the road speed at which changes take place.

Signals from the governor are fed to a relay box to control the relationship between generator current and the magnetic-particle couplings.

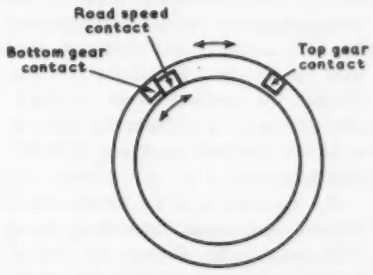


Fig. 3 Principle of governor contacts in the Smith system

A monthly review—under basic headings—of the latest control engineering developments for all industries; specially edited for busy technical management, plant and production engineers, chemical engineers, etc., who are not specialized in instrument and control systems

IDEAS APPLIED . . .

. . . to POSITION

Numerical control for a jig borer

M. SALTER,
Applied Electronics Laboratories, G.E.C.

A new transistorized position control system by the G.E.C. uses precision leadscrews as independent measuring elements and incorporates novel zero setting features.

The control system described is of the point-to-point or coordinate setting type, in which the table of a machine tool is brought to a final position, specified numerically on punched cards or tape, without regard to the path taken. The controller was originally developed for use with the Model 2436 jig borer made by the Newall Engineering Co. Ltd. (see Fig. 1), and the description relates particularly to that version: the general principles and most of the component parts, however, have potential applications wherever an accurately controlled linear motion is needed.

Measuring leadscrews and digitizers

One of the basic problems in the design of a coordinate setting controller is the choice of a measuring system, and the one adopted here is a combination of a precision pilot leadscrew and a specially developed digitizer. The pilot leadscrew takes no part in the mechanical drive to the table and so can be very lightly loaded for high accuracy and long life. It is used to set up a reference position, through the medium of an anti-backlash nut carrying a magnetic pick-off, to which the table is driven by a follow-up servo.

The digitizer is a six-decade coded decimal instrument, measuring up to 1000 revolutions in steps of 1/1000 revolution, and is geared 1:1 to the pilot leadscrew to provide measurements of linear displacement in steps of 0·0001 in. up to the full length of the screw. The output codes are generated by groups of magnetic pick-offs, operating at 15 kc/s, which sense the positions of a number of toothed wheels. There are no moving contacts to wear and cause erratic operation.

Servos

From the block diagram (Fig. 2) it will be seen that there are two servos to each machine axis, one controlling the pilot leadscrew and one controlling the table movement.

The pilot leadscrew is driven by a 1/20 h.p. d.c. motor through a two-speed epicyclic gearbox, and the motor is run at either of two pre-set speeds. This combination gives a four-speed on-off control with speeds ranging from 90 in/min to 0·03 in/min, which are selected in turn by logical circuits that compare the output from the digitizer with the number punched on a card. The comparison is done one decade at a time, starting with the most significant decade, and the higher speeds are associated with the more significant decades. To avoid the possibility of over-shoot errors the decades already set are re-checked after every speed change, and any correction needed is made at the new (lower) speed. The sequence is only terminated when a complete check of all six decades has been made without revealing an error.

The servo drive to the table consists of a conventional leadscrew and two electric motors, either of which may be engaged by a magnetic clutch. Three pre-set traverse rates are available, ranging from 90 in/min to 0·06 in/min, and these are selected in turn by logical circuits controlled from the magnetic pick-off on the pilot nut.

The logic is of the switch-off-at-

Fig. 1 This experimental version of the control gear was shown at the National Industrial Production Show, Canada, in May

coincidence type, adapted to ensure that the final slow approach always occurs in the same direction. As soon as the final movement has been completed, electrically-actuated hydraulic clamps come into action to lock the table in position.

The pilot leadscrew and table control sequences are overlapped as far as possible to save time; the only restrictions are that the table is not allowed to move until the clamps are fully released, or to enter the final stage of its movement until the pilot leadscrew sequence is complete. As a result of this overlap the total time required for a full 24 in. movement is less than 30 sec.

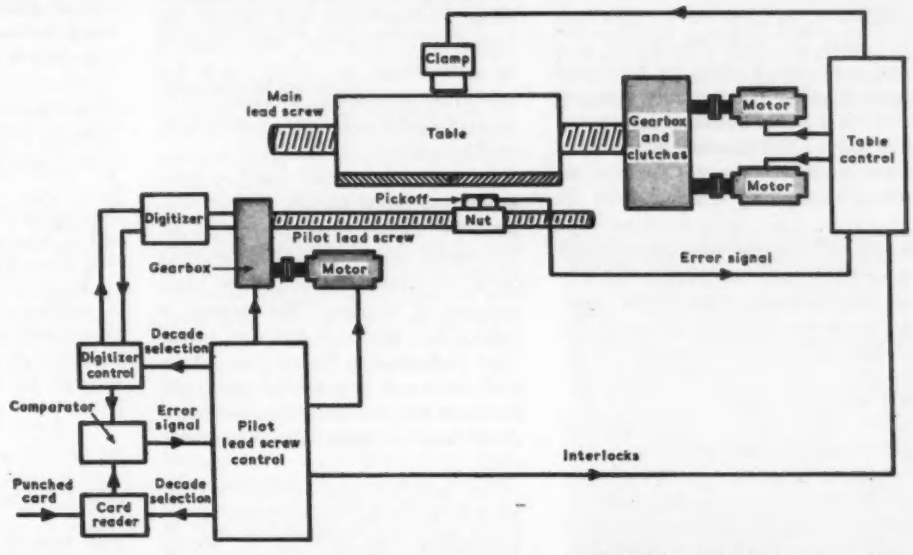


Fig. 2 The block diagram for one machine axis. The other axis is identical

Transistor and switching circuits

The a.c. output signals from the digitizer and pick-off are at low level, requiring amplification and phase sensitive rectification before they can be used to control logical operations. The amplifying circuits and the subsequent logical circuits all employ transistors and semiconductor diodes, mounted on plug-in printed boards. The result is a compact assembly of easily replaceable sub-units, with excellent long term reliability.

The output signals from the logical circuits are not themselves suitable to operate the motors: this function, together with certain other operations where similar considerations apply, is carried out by heavy duty relays.

Input media

The standard input medium is a parallel reading card reader, which is supplemented by a set of decade dials. The parallel nature of the card reader allows repeated readouts to be made on demand, independently for either machine axis, so that a separate temporary store for input data is not necessary. Standard Hollerith cards are used, one for each pair of coordinates. An alternative version will use a Creed Model 92 tape reader, with blocks of transistor registers for temporary storage.

A reversing switch allows both right and left-hand parts to be made from the same input data, as well as accommodating any different axes conventions used in the dimensioning of drawings.

Zero setting

A particularly useful feature of the controller is an arrangement whereby the zero of the measurement system may be re-set, by semi-automatic means, to suit the actual position of the work on the table. It is only necessary to clamp the blank component in the correct orientation (if any) relative to the slide directions, and then to move the table by hand control so that a reference point on the blank comes directly under the spindle. A card punched with the coordinates of this reference point as given on the component drawing is then inserted in the card reader, and the measurement system is automatically re-zeroed so that its reading is the same as the card.

The method used for this re-settling depends on an unusual feature of the digitizer coding. The code used is as follows:

Decimal digit	*Code*
0	10011
1	10001
2	11001
3	11000
4	11100
5	01100
6	01110
7	00110
8	00111
9	00011

The particular feature of interest is that the whole code pattern may be shifted any number of places relative to the decimal digits by a cyclic rearrangement of the code digits, combined if necessary with logical inversion. For example, the cyclic rearrangement obtained by transferring the right-hand column to the left-hand side gives the code pattern:

11001
11000
11100
etc.,

which is readily seen to be the original pattern, shifted up by two places. Similarly a logical inversion of the original pattern gives:

01100
01110
00110
etc.,

which corresponds to a shift of five places.

A combination of operations of this type on each decade of the digitizer output, together with logical control of the carry from one decade to the

next, enables the digitizer output to be interpreted as reading from any arbitrarily chosen zero. In practice the cyclic re-arrangement is controlled by solenoid operated stepping switches, with logical inversion by means of miniature auto transformers which invert the phase of the 15 kc/s signals from the digitizer.

An essential preliminary to this resetting of the digitizer is to bring the pilot nut into its coincidence position relative to the table. This operation makes use of some of the pilot leadscrew logic circuits, controlled now by the output of the magnetic pick-off. Once the nut is in the coincidence position the setting up of the stepping switches is initiated on a 'shift and try' basis, in which one decade at a time is examined while the associated stepping switch is repeatedly operated until the digitizer and card reader outputs agree. The process of checking through the six decades is repeated several times, only ceasing when all carry errors have been removed: this re-cycling is made necessary by the order of decade selection, chosen to suit the positioning sequence, in which the more significant decades are examined first.

Self-checking facilities

The system is designed to be a large extent self-checking. The error signals in both servo loops are continuously monitored until the clamps are finally applied, and any error arising from vibration, for example, causes the control sequence to revert to an appropriate earlier stage for re-positioning. Moreover, faults resulting in forbidden combinations of data (e.g. failure of a contact in the card reader, or two holes punched in one column of a card) cause the sequence to be stopped and a warning light shown. Only when the positioning sequence has been satisfactorily completed in all its stages is the green sequence complete signal given.

Performance

The two major causes of error are inaccuracies in the pilot leadscrew and inconsistencies in the table overshoot when stopping from the slowest speed. The prototype pilot leadscrew, which was made by the Newall Engineering Co. Ltd., had maximum pitch errors of about $\pm$ 0·0002 in. over a length of 18 in. It is thought that this standard can be maintained and even improved in later models.

The magnitude and consistency of the overshoot in the final table movement is dependent on the wind-up in the drive and the friction of the slides. Wind-up is removed as far as possible by reversing the drive for a short period immediately the correct position is reached (backlash in the gearing prevents any reverse movement being transmitted to the table).

The slide friction in the first experimental model was high, as a standard machine with plain slides of a rather stiff type was used. In spite of this the errors that could be attributed to variation in overshoot were within a range of $\pm$ 0·00015 in., and the total errors due to all causes in an extended series of tests were well within the target of $\pm$ 0·0005 in. Improvements in slide design are being made for later models, and this should result in an appreciable reduction in maximum errors.

Remote control in TV

BBC-TV have taken over for experimental trial a remotely-controlled television camera developed by their engineering division. The camera is located in a television interview studio near Broadcasting House, but all its functions—pan, tilt, focus, zoom and iris—can be controlled from the studio at Alexandra Palace, about six miles away.

The camera tripod carries a special head in which the panning and tilting movements are operated by servomotors. Additional servomotors, mounted on a plate fitted to the camera body, are arranged to drive the focus, iris and zoom controls. The operation of the motors and their associated servo amplifiers is controlled over cable circuits from a special console at Alexandra Palace, or alternatively by the interviewer in the studio who is provided with push-buttons for the purpose. Apart from the console, all the control equipment is in the interview studio. In addition to the power supply equipment this cabinet houses the transistorized servo amplifiers, control relays and four additional sets of potentiometers for controlling the camera functions when under local control.

Local control is effected by using a set of four push-buttons in a small box at the end of a trailing lead which, in conjunction with change-over controls, allow the camera to be operated locally.

The interviewer, by pressing the appropriate buttons, can cause the camera to show himself and perhaps two other people in long-shot and then bring any one of the three people into close-up as required. The camera will pan and tilt as necessary, and for each shot the degree of pan, focus and zoom will be automatically adjusted to suit the particular situation.

. . . to FLOW

Measurement of corrosive fluids

A novel differential pressure transducer has been designed by Drs. Li and Lee of the Massachusetts Institute of Technology. Originally developed for measuring the flow of corrosive fluid it has been used in various applications where long-term stability under severe conditions has been an essential requirement.

The principle of operation is easily

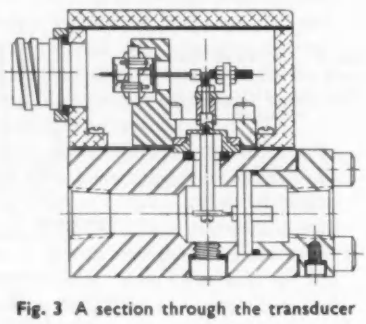


Fig. 3 A section through the transducer

seen from the diagram (Fig 3). The two pressures, each up to 4000 lb/in², are brought into the body of the transducer from opposite sides, and kept separate by a diaphragm. Deflexions of the diaphragm are transmitted by a mechanical linkage, through a flexible seal, to an unbonded strain gauge (6 V a.c. excitation) in the upper chamber. The diaphragm deflexions are minute, being of the order of 0·0035 in. The differential pressure ranges from $\pm$ 5 lb/in² f.s. up to $\pm$ 1000 lb/in² f.s., with a frequency response of 1–1000 c/s ($\frac{1}{2}$ dB). The transducer is light (15 oz) and highly stable with respect to temperature (− 50 to 180°C) and vibration. The output is 25 mV f.s. and the linear accuracy $\pm$ $\frac{1}{2}$%.

The transducer is to be assembled in this country from parts manufactured in the U.S.A. The estimated price of the unit is £180. Further information about the device is available from Lintronic Ltd.

NEWS ROUND-UP

from the world of control

GUIDANCE

Automatic interplanetary station

As CONTROL goes to press a 613 lb automatic interplanetary station is about to round the moon, which it may well pass at a distance of 10,000 km before becoming a satellite of the moon and/or earth. This further space launching follows hard on the heels of the Lunik II probe, discussed below.

From a control viewpoint the most interesting thing is the intention to guide the vehicle round the moon by firing radio-controlled retro rockets when the vehicle enters the moon's gravitational field. According to Tass, radio will be used to 'control the elements of the orbit of the interplanetary station.' Furthermore it looks as if the Russians are guiding the vehicle during its ballistic, or free-flight, phase. Presumably control rockets will be fired by radio to correct the vehicle's earth-moon orbit, its position having been fixed by transponder-radar techniques.

The use of retro rockets to cause the device to go round the moon presupposes the existence of an extremely fast computing facility, possibly of digital differential analyser type.

There is also some suggestion that the Russians have made an advance in structural engineering, as the ratio of structure weight to fuel weight of the device would appear to be very low.

Russian moonshot success

The Soviet space rocket, 'Lunik II,' which, with its 860 lb of instrumentation hit the moon at 0002 hours, 24 sec, Moscow time on September 14 (signals received at Jodrell Bank ceased at 1002 hours, 23 sec, on September 13) must surely rank with man's greatest engineering achievements. Details, however, are few and we can do little more than record the event.

To hit the moon at all is quite an achievement, but to be within 250 miles of a particular point on the moon, some 250,000 miles from the launching position is much more enterprising. On examination, however, the problems of navigation and guidance which arise are no more difficult than those for an intercontinental ballistic missile. It follows that any nation with an ICBM has a potential moon probe.

Roughly, for a 5000-mile range ICBM to hit within 10 miles of its target, its velocity vector error must be no greater than 0·03°, and the velocity error itself not greater than 0·01%. This is much the same order of accuracy as must have been attained by the Soviet probe.

Conventional guidance ?

No guidance details are available but it is probable that more or less conventional military missile techniques were used, and here the norm is to control as accurately as possible as early in flight as possible. It is obviously simpler to correct a small error at short range than a much magnified error at longer ranges.

It is likely that inertial guidance plus some radar-radio control, was employed during the boost, or main motors 'on,' phase and this may well have been sufficient. As the rocket is known to have emitted a sodium flare, it was suggested that position at a point during the ballistic, or free flight, phase was determined optically from the earth and control rockets were fired by radio to bring the vehicle back on course. Some device to give the attitude of the vehicle would have been necessary, for example a stable platform. Such control during the ballistic phase is not unknown as a means of catering for small unpredicted errors. However, Academician Leonid Sedov, head of the Russian Academy of Science's space flight group, has reported that the capsule was uncontrolled.

Nevertheless, to suggest that conventional guidance techniques were employed is far from decrying the moon probe's sensational success.

Inertial navigation

A £150,000 extension to Ferranti's Crew Toll, Edinburgh, laboratory, which was opened last month, is to be used to produce a new series of high-precision gyroscopes and accelerometers for inertial navigation systems. This is no new venture for Ferranti as they have been making such instruments for eighteen months or so.

The manufacture of instruments for inertial navigation presents as many problems as basic design. No dust particles greater than about 0·5 micron in size, or excess moisture, are allowed in the assembly and inspection areas which, together with the store for finished parts, are temperature, humidity and dust controlled. A system of double air locks is installed between the machine shops and a cleaning room equipped with ultrasonic cleaners, and a second double air lock between the clean room and the air-conditioned store room ensures the minimum transfer of air between conditioned and non-conditioned areas.

The main air conditioning plant uses an absorption cooling machine instead of compressors, in order to eliminate vibration. The temperature is controlled at 72°F, ± 1°F, at 8 points within the air-conditioned areas, and good draught-free diffusion of air is obtained by means of a special perforated dome type secondary air diffusers placed continuously across the ceiling. This secondary diffusion, in spite of 16 air changes per hour, has the effect of moving the air imperceptibly downwards to be extracted through grilles at floor level. As excessive humidity is harmful, the air-conditioned plant automatically controls this to a maximum of 45% relative.

Testing section of Ferranti's (Edinburgh) inertial navigation laboratory

Isolating vibration

Ground transmitted vibrations are isolated from the test area in which special mountings have been installed carrying test equipment for the instruments. One instrument, for example, requires that

the mounting carrying the test gear shall not be subjected to rotations greater than 1 second of arc or translations with acceleration greater than 0·0001 g.

In a pit underneath the main floor of the test area, there are three large reinforced concrete blocks, one weighing about 60 tons and the other two about 40 tons each. The large and one of the small blocks, are each mounted on four rubber pads and fitted with rubber side buffers to isolate vibration in the vertical and horizontal planes respectively. These two blocks, the tops of which come to within about 12 in. of the underside of the suspended flooring over the pit area, carry aluminium alloy pillars filled with concrete, each weighing approximately 1 ton, which pass through the flooring.

A flexible dust seal is fitted between each pillar and the floor so that no vibration is transmitted from the floor. The third concrete block carries one test pillar only and is suspended on 16 helical coil springs, to give better isolation from disturbance than the other two. Damping is achieved by dashpots filled with silicone oil.

Components and systems

Initially, work will be concentrated on components only, but the scope will be extended to include the production of inertial navigation systems. Much of the present work is concerned with a single-axis floated rate integrating gyro, manufactured under licence from the Kearfott Company, U.S.A., and a pendulous integrating gyro accelerometer by Ferranti. Future work will cover smaller gyros of roughly equivalent performance to the present design. All instruments produced at Edinburgh are based on the fluid supported system evolved in the U.S.A.

EE's Army g.w.

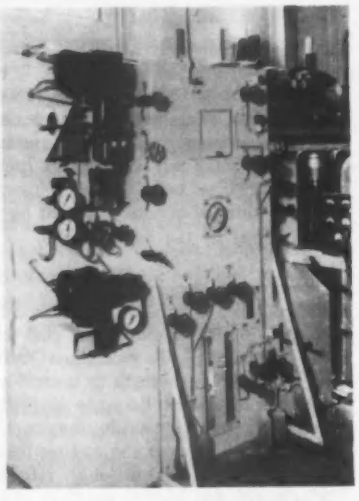
The Guided Weapons Division of English Electric Aviation is developing a new 'Army Corps Support Weapon' under a Ministry of Supply contract. This new—at present unnamed—short-range weapon, is the second E.E. is working on for the Army. The other is the Thunderbird ground-to-air semi-active homing anti-aircraft weapon which is now in service. English Electric are also concerned with the American 'Corporal' missile which the British Army has adopted.

—— ELECTRICITY ——

Fuel cell control

Sunvic Controls, who provided the equipment for automatically balancing pressures of oxygen and hydrogen to F. T. Bacon's hydrogen-oxygen cell, are a little disturbed that the national press may have given the impression that the complexity of the control equipment is out of all proportion to the rest of the gear. Sunvic point out that the control panel, illustrated, could handle up to 10 such 40-cell units, each having a capacity of 2·5 kW at 32 volts. Furthermore, the Sunvic instruments constitute virtually all the control equipment, the various other 'black boxes' being used for research.

The equipment comprises two differential pressure transmitters, a two-term



Sunvic equipment balances the fuel-gas feed to N.R.D.C.'s hydrogen-oxygen cell built by Marshalls of Cambridge

pneumatic controller with built-in desired value setting and a valve positioner. Oxygen and hydrogen are fed to the cell at 400 lb/in² and must be accurately balanced, otherwise the porous nickel electrodes might be ruptured or distorted. One differential pressure transmitter, therefore, notes any unbalance and feeds a 3–5 lb/in² signal to the controller, the output of which actuates the valve positioner mounted on the hydrogen control valve. The second differential transmitter is used to ensure that 2 lb/in² pressure difference is maintained, so that the fuel gases cannot penetrate the fine pored surfaces of the electrode.

The fuel cell was built for N.R.D.C. by Marshalls of Cambridge.

—— EDUCATION ——

Environmental Engineering

A Society of Environmental Engineers has been formed to provide a forum, by meetings, publications and visits, for the exchange of information and views among those engineers who are concerned with the development of equipment to withstand shock, vibration and other forms of environmental conditions.

The S.E.E. intend holding their first Annual General Meeting on March 30, 1960, at 2.30 p.m. at the House of the Royal Society of Arts. The present Committee consists of V. G. Weake (Chairman), P. Grootenhuis, E. H. Ingamells, F. I. L. Knowles, D. A. Nutt and C. Rex-Hassan (Secretary).

Membership and associate membership is open to scientists and engineers working on these subjects, and sponsor membership is open to firms similarly concerned. Details may be obtained from the Secretary, The Society of Environmental Engineers, 42 Manchester Street, London, W.1.

DATA PROCESSING

Eight 803s for U.S.A.

Elliott Bros. have an initial production programme for 14 of their new 803 small digital computers, nine of which are on order, eight for U.S. installations. It may be recalled that one Elliott 802, the predecessor to the 803, was delivered to the United States earlier this year. The 803 is in effect a completely transistorized version of the 802; it has longer word-length, greater internal storage and has been restyled. Three of these machines will form part of the type 609 process control system of Information Systems Inc, a subsidiary of the American firm, Panellit. Both British Panellit and Elliott Brothers are, of course, members of the Elliott-Automation Group. One 609 system is to be installed at the Gulf States Power Co's Nelson Station

STILL AT THE HELM? The—at the time—First Lord of the Admiralty, the Earl of Selkirk, at the control console of EMI Electronic's Emiac II analogue computer recently installed at the Baginton, Coventry, works of Sir W. G. Armstrong Whitworth Aircraft. Mr. C. Bayly, Executive Director and Chief Engineer of the company's guided weapons division, is explaining to the First Lord that the machine is capable of studying the performance of guided weapons or aircraft systems before they have left the drawing board

at Lake Charles, Louisiana, and two more will be delivered to E.I. du Pont de Nemour's chemical processing plant at Beaumont, Texas. CONTROL understands that Information Systems is producing nine 609's in all, so it would appear that the eight 803's for America, plus the original 802, will be used in the process control role.

Airline seat reservations

As reported in these columns in April, Ferranti-Packard Electric, the Canadian subsidiary of Ferranti Ltd., have received a $2 million order from Trans-Canada Airlines for booking office and communications equipment for a seat reservation system. TCA have now ordered a fully-transistorized computer from Ferranti-Packard, bringing the total cost of the system to nearly $3·5 million.

The computer system consists of two identical machines both capable of using a common set of magnetic tape and input/output equipment and employing solid state transistor circuitry throughout. It is intended for continuous on-line working and while one computer can be handling reservations the other can be handling statistical work.

This central computer will be located in Toronto, and each TCA booking office in Canada and the U.S.A. will have direct wire access to the mass of flight and reservation information stored in the computer memory. This will be carried out by means of general purpose computer input/output devices known as transactors.

Narec's transistorized core

A $200,000 contract has been received by Telemeter Magnetics, U.S.A., for a large scale high-speed core memory having a capacity greater than 850,000 bits. The 'completely transistorized' core memory is to be used in Narec—Naval Research Electronic Computer—an asynchronously controlled machine which operates in parallel in the binary number system.

Atlas outstrips Mercury

Following the recent announcement that N.R.D.C. are supporting the development of EMI Electronics' Emidec 3400 and Ferranti's Atlas, a few details have been released on the latter machine. Atlas is a large capacity high-speed fully-transistorized digital computer, which is expected to be around a hundred times faster than the Ferranti Mercury. The first Atlas, the prototype for the Ferranti Atlas, which is being built by engineers of Manchester University and Ferranti for installation at Manchester University, should be in operation by 1961/62. According to Ferranti, the simple operation of adding a number into the accumulator register will take 0·2μ sec and more complicated functions will be correspondingly faster than with current machines. Atlas should be able to operate on a continuous basis for it is capable of switching to another programme if the main programme is held up for any reason.

IBM computer language

Commercial Translator, a new language for instructing or programming digital computers for commercial problems, has been developed by IBM. It is understood to consist of normal English words which are converted in the computer into detailed machine instructions. A typical statement in Commercial Translator might be 'If stock level is less than 1000 or reserve level is zero then set order amount equal to 5000 minus stock level; move order record to order file; go to next item'.

Such simplification has been available for some time in scientific work, with the aid of Fortran (Formula Translation). In scientific work the precise mathematical terms normally used are, of course, much more adaptable to translatory techniques.

—ATOMIC ENERGY—

Dowty's dilemma

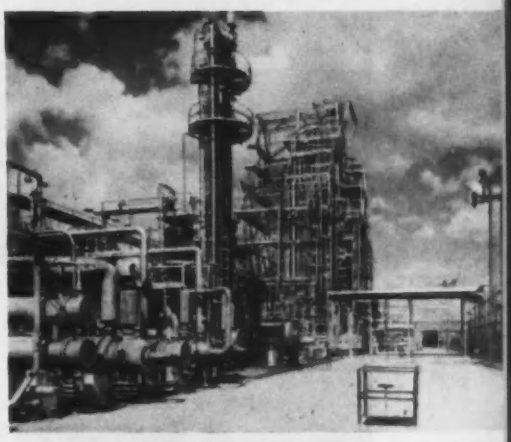
Sir George Dowty, Chairman of the Dowty Group, made a rather pessimistic reference to the nuclear field in his recent statement to shareholders. This hint of growing mistrust in nuclear work is underlined by a recent release which states 'Dowty Group Ltd., after careful consideration of the nuclear power station potentiality, have decided to diversify the activities of their technical facility at Brockhampton Park, the headquarters of Dowty Nucleonics Ltd., in order to expedite the development of new and more promising projects. The technical investment in the nuclear industry and the sales to date have been small compared with the other businesses of the Dowty Group. The potential, both at home and abroad, no longer appears to justify even this comparatively small technical effort. . . .'

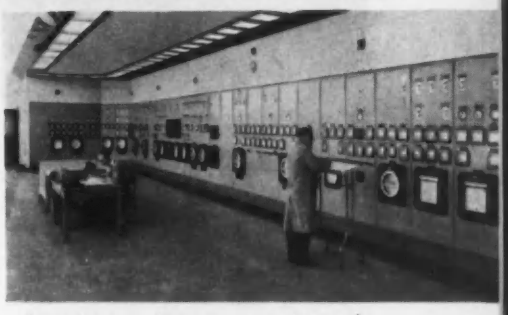
Sealed gas lubricated circulators and compressors will be carried on by Dowty Fuel Systems Ltd. and Dowty Seals will provide seals for the nuclear industry.

——CHEMICALS——

ICI's third Wilton plant

High purity ethylene is being produced by ICI at Wilton, Yorkshire, at a rate of some 110,000 tons a year now that the third olefine plant is in operation. An increase in this output to 140,000 tons a year by modifying the new plant, and the other two plants already in existence at Wilton, is now being considered. This third plant raises ICI's olefine capacity by 60% but so high is the degree of automatic control employed that it requires 13 men only for each of the four shifts worked.





Control room for gas separation and refrigeration section of ICI Wilton's third olefine plant. Above, part of the gas separation plant

In the three olefine plants, there are altogether 36 continuous and fully automatic analysis instruments transmitting their readings to recorders in the control rooms. Non-dispersive infra-red spectrometers are used extensively for the analysis of simple mixtures of light hydrocarbons. For more complex compositions and low concentrations, a chromatograph or an instrument employing chemical analysis is used. In addition to automatic analysers, a considerable staff is engaged in the laboratory on analysis concerned with control of the unit and the checking of product purities. Here again, full use is made of modern instruments such as mass spectrometers and chromatographic analysers. Eleven miles of air signal piping are used for automatic control.

——ROADS——

Autocontrolled road stone plant

Better mixing and higher quality of road surfacing materials should result from a Midlands road stone supplier's decision to install automatic equipment to control the operation of a mixing plant he is now constructing. The control system, which is by Elliott Bros., depends essentially upon the use of strain-gauged load

Control console of the automatic road stone mixing plant Elliotts are instrumenting for a Midlands supplier

cells as weight-measuring elements for the operation of recorders, indicators and controllers. The installation will weigh materials to a given formula and pass the aggregate to mixing lines for check-weighing before heating and mixing with other ingredients.

Varying amounts of different mixes can be produced simultaneously on the two mixing lines which the equipment controls.

A console, illustrated, in the control room indicates to the plant operator the amount of each ingredient to be used for a selected mix. Signal alarms on the central panel inform him that the correct sequence of operation of the mixer, heater and of the check-weigh hopper doors occurs. A master time controller governs the mixing time and correlates heater and boiler timing with quantity measurement of the flux, oil and bitumastic compounds. All operations are controlled by an interlock system.

——NEWS BRIEFS——

Hagan Controls Ltd has been set up by Plessey (90% shareholding) and Hagan Chemicals and Controls Inc, U.S.A., to manufacture and sell Hagan automatic control equipment and 'Kybernetes' data processing equipment in Britain and the Commonwealth except Canada.

Cold curing silicone rubbers for the electrical, electronic and aircraft industries are now in production by Midland Silicones.

Evershed-Powertronic Ltd. has been formed in Canada by Evershed and Vignoles to handle their instrumentation work. Electrical testing instruments, such as the Megger, will continue to be handled in Canada by R. H. Nichols Ltd.

Westool Ltd have opened a London Office under A. C. Stewart at 2 Ashley Place, Victoria, S.W.1.

Technicon Autoanalyzers for continuous automatic chemical analysis, will be available in British-made form from Technicon Instruments by the end of this year.

Magnetic amplifiers of high stability have been commissioned by B.T.H. from the Special Products Division of Ultra Electric for the A.E.I./John Thompson nuclear power station at Berkeley, where they will form part of the reactor control system.

LOOKING AHEAD

Unless otherwise indicated, all events take place in London. BCS British Computer Society. BritIRE British Institution of Radio Engineers. IEE Institution of Electrical Engineers. RAeS Royal Aeronautical Society. SIT Society of Instrument Technology.

WEDNESDAY 14 OCTOBER
An Automatic Analogue Computer for Missile Homing Investigations by J. G. Thomason. 6.30 for 7.0 p.m. S.I.T.

FRIDAY 16 OCTOBER
Programming a Computer by A. C. Quarterman. 7 p.m. Junior Institution of Engineers

THURSDAY 22—SATURDAY 24 OCTOBER
Eighth Annual S.I.M.A. Convention, Brighton

THURSDAY 22 OCTOBER
Conference on *Computers for the Smaller Firm*. Details: Hon. Sec., Central London Productivity Association, c/o Shell-Mex & B.P. Ltd., 1 Kingsway, W.C.2

TUESDAY 27 OCTOBER
Discussion on *Future Trends in Memory Stores for High-speed Digital Computers*. I.E.E.

FRIDAY 30 OCTOBER
Planning a Computer Job by M. G. Ferrand. 7 p.m. Junior Institution of Engineers

TUESDAY 3 NOVEMBER
An Analogue Electronic Multiplier using Transistors as Square-Wave Modulators by P. Gleghorn. I.E.E.

WEDNESDAY 4 NOVEMBER
Half-day Symposium on *Input-Output Devices*. 3 p.m. and 6 p.m. Brit.I.R.E.

TUESDAY 10—SUNDAY 15 NOVEMBER
International Exhibition and Congress on Laboratory, Measurement and Automation Techniques in Chemistry. Basle

THURSDAY 12 NOVEMBER
Optimum Setting of Water Turbine Governors by H. Schiott. 6.30 for 7.0 p.m. S.I.T.

FRIDAY 13 NOVEMBER
Electronic Components by W. C. C. Ball. 7 p.m. Junior Institution of Engineers

MONDAY 16—FRIDAY 20 NOVEMBER
The Fifth International Automation Exposition. New York

TUESDAY 17 NOVEMBER
Discussion on *Sequence Networks versus Summation Transformers for the Derivation of Single Quantities for Protective Relaying*. I.E.E.

WEDNESDAY 18 NOVEMBER
Half-day Symposium on *Electronic Digitizing Techniques*. 3 p.m. and 6 p.m. Brit. I.R.E.

WEDNESDAY 16 DECEMBER
Random Inputs and Load Variations by J. F. Coales. 6.30 for 7.0 p.m. S.I.T.

LOOKING FURTHER AHEAD

TUESDAY 5—THURSDAY 7 JANUARY 1960
Symposium on recent mechanical engineering developments in automatic control. Details: The Secretary, The Institution of Mechanical Engineers, London

MONDAY 11—WEDNESDAY 13 JANUARY 1960
6th National Symposium on Reliability and Quality Control in Electronics. Washington. Details: R. Brewer, General Electric Co. Ltd., Wembley, Middx

WEDNESDAY 20—THURSDAY 21 JANUARY 1960
Managerial and Engineering Aspects of Reliability and Maintenance of Digital Computer Systems. I.E.E.

WEDNESDAY 10—FRIDAY 12 FEBRUARY 1960
Solid State Circuits Conference, Philadelphia. Details: The Chairman, 1960 Solid State Circuits Conference, General Electric Co., Electronics Laboratory, Electronics Park, Syracuse, New York, U.S.A.

WEDNESDAY 17 FEBRUARY 1960
Faraday Lecture—*Electrical Machines* by Prof. M. G. Say. Central Hall, London

MONDAY 22—FRIDAY 26 FEBRUARY 1960
1st Engineering Materials and Design Exhibition. Earls Court

FRIDAY 10—SUNDAY 26 JUNE 1960
British Exhibition U.S.A. New York

SATURDAY 25 JUNE—TUESDAY 5 JULY 1960
Moscow Congress for Automatic Control. Details: International Federation of Automatic Control, Prinz-Georg-Strasse 79, Düsseldorf, Germany

PEOPLE IN CONTROL

by Staffman

John E. Coleman has relinquished his major shareholdings in Spesco Developments (the plastic film packaging people), which will now be controlled by I.C.I., to devote his full attention to the Gresham Lion Group. I gather that he is using the proceeds of the sale to promote Gresham's activities in the automatic process control fields. He said to me 'we act as independent consultants on a fee basis normally—but not always—using other manufacturers' equipment as adjuncts to G.U.S., the Gresham unit sequencing system, our variable programme controller'.

G. G. Ballard, who at 29 has been appointed Chief Engineer of Elliott-Automation subsidiary Elliott Nucleonics, joined the Group in 1948. He was for six months at Harwell as the Company's engineer concerned with the installation and operation of the instrumentation for the Neptune zero energy experimental

MEDLOCK presides

BALLARD engineers

research reactor. He will now be responsible for engineering special instrumentation for the Bradwell nuclear power station as well as for other Elliott work in the nuclear field.

I was surprised to hear that **L. A. Sweny,** Manager of Marconi's Aeronautical Division, has been seconded to Hovercraft Development Ltd. The latter is an N.R.D.C. company and it will be recalled that the prototype Hovercraft the SR-N1 was built by Westland subsidiary Saunders Roe for N.R.D.C. Marconi's are, of course, members of the English Electric Group but I am assured that this does not mean that E.E. have any financial interest in Hovercraft Development, and that this is a private venture on Sweny's part. He is a Director of Hovercraft along with the inventor of the machine, **Christopher S. Cockerell,** another ex-Marconi man.

B. J. O'Kane takes over from Sweny at Marconi's.

This year's President of the Society of Instrument Technology is **R. S. Medlock,** Technical and Home Sales Director of George Kent Ltd. Medlock is also a consultant to CONTROL and has been active in the world of instruments for many years. He joined George Kent in 1935 as an electrochemist and is still interested in such analytical techniques as those concerned with pH and oxygen analysis. He is keenly interested in the development of new industrial methods and equipment, particularly in connexion with automatic control.

I hear from **J. F. A. Bryen** of International Computers and Tabulators (his rather high-sounding title is 'Computer Systems Research and Advice') that he is now concerned with the systems study and application of computer production control to all twelve of I.C.T.'s production factories. This year he has spent much of his time at the largest of these—the former Powers-Samas plant at Croydon. I.C.T. would appear to be somewhat unusual in that they have no objection to taking their own medicine.

I.C.T.'s associate company the Data Recording Instrument Co. have appointed **C. G. Hutchinson** as General Sales Manager. This company specializes in magnetic tape decks for use as input and output mechanisms for computers.

R. J. A. Paul of Cranfield's College of Aeronautics, who reviews the Farnborough display on page 104 of this issue, tells me that the Sperry Gyroscope radio track guide—an airborne navigational analogue computer—described in last month's CONTROL (page 116) formed the basis of a research thesis at Cranfield. A Sperry-sponsored research student, **C. Britnell,** carried out the work under the direction of the College's Electrical Department.

J. C. Wells, who left Solartron recently to join Baldwin Industrial Controls as Chief Engineer, Hydraulics Servo Division, holds that the potentialities of hydraulic servo techniques are not appreciated by industry. 'I am sure that the present bias towards electronic servos is a passing phase' Wells told me. He pointed out that a 15 h.p. hydraulic motor having an acceleration of 750,000 rev/min. sec is about the size of a 3 h.p. electric motor.

K. Fearnside who joins Smiths Aircraft Instruments' Board as Director of Research, was Research Manager at

FEARNSIDE researches

PARTOS accumulates

Smiths' Cheltenham factory. He was at A.E.R.E., Harwell, for several years and joined Isotope Developments as Technical Director in 1950. He took charge of Systems Studies in Smiths' GW Department in 1953 and was Research Manager for two years.

Formerly Chief Engineer of Panellit Ltd., Dr. **Paul Partos** has joined Honeywell Controls where he will supervise engineering design for the company's data processing activities. He feels that the immediate advantages of applying industrial data processing to a complex process are so great that the long-term function is often overlooked. He told me he believed that function to be 'to accumulate the data necessary to the design of a closed-loop control system for the process—data about the process itself and about its automatic control. In other words' he went on 'I regard data processing less as an end in itself and more as an essential phase in the evolution of the fully automatic industrial plant.'

Opperman Gear's Sales Director, **A. Black,** has been appointed to the Board of Limitorque Valve Controls, an associated company. Black's co-Director **J. M. Opperman** tells me that they are working on the development of hydraulic actuation for Limitorque valves and that the main use for these types will be in marine applications. Orginally developed as an on-off control for the oil industry, 80% of the Limitorque valves in service are electrically operated; about 15% are pneumatic and the remainder are 'specials.'

New for Control

A monthly review of system components and instruments

AMPLIFIER

for low-level signals

The new Solartron wideband d.c. amplifier (type AA 900) has been designed for the distortion-free amplification of low-level signals from transducer sources such as pressure pick-ups, thermocouples or photocells. It has a bandwidth of d.c.

A compact amplifier

to 40 kc/s (3 dB) and an exceptionally low equivalent input drift of less than 2 μV over 40 h. Produced with integral mains power supply, six such amplifiers can be fitted into a standard 19 in. rack.

The low figures of drift and noise achieved have been made possible by use of advanced negative feedback techniques, including continuous 'chopper' correction. Noise and ground loop problems are minimized by holding the common voltage rail above chassis, and the input above nominal earth.

Tick **No 171** on reply card

CONTROL VALVES

leak-free, long life

Drallim Industries Ltd. have introduced a range of fine control valves designed to provide flow control of gases and liquids with a positive leak-free performance over a long life. Control is through a number of rotations of the handle covering negative to maximum at a gradually increasing flow rate. The control and valve operating stem are separated by a resilient diaphragm, and by an adjustable stop each valve is set to provide an absolute seal without straining the operating handle or damaging the valve seat or sealing member. They are recommended for a wide range of uses at varying pressure from high vacuum to 200 lb/in².

Tick **No 215** on reply card

SCINTILLATION COUNTER

for medical use

A recent addition to the range of nuclear equipment for medical use by Ekco Electronics Ltd. is a lightweight scintillation counter (type N618) with a directional shield (type N651). The counter is constructed in a sealed stainless steel container enabling it to be cold-sterilized. The output from the photomultiplier tube is fed via a cathode-follower stage to the permanently-attached cable from which connexions can be made to a suitable ratemeter or sealer requiring a minimum output of 5 V.

Tick **No 172** on reply card

HUMIDITY CONTROLLERS

a complete range

A range of humidity controllers for two-position low and line voltage control, and low voltage proportional control has been introduced by Honeywell Controls Ltd. Models in the range will control modulating or two-position motors or can be used to control pumps, motors and fans directly.

The proportional controller is for use with a modulating motor and can be used for control of humidification and dehumidification in all the usual air conditioning applications. It has a range of 20–96% R.H. with a modulating range of 10% R.H.

Two humidity controllers

The range includes several types of two-position controllers, featuring both single and double throw switches. Two types of controller are offered; those using open-contact snap-acting switches which ensure a differential accuracy of 2% R.H. at mid-scale; and those using totally enclosed mercury switches for heavy loads and use in hazardous atmospheres.

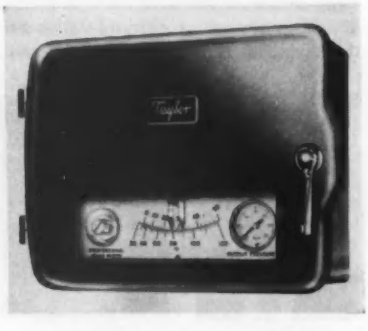
The range of controllers features human hair sensing elements which guarantee a high degree of stability.

Tick **No 173** on reply card

CONTROLLER

air-operated

Taylor Controls have introduced a new air-operated controller. It is furnished in two models, adjustable proportional response with band between 1% to 30%, and fixed high response. The action is



Large output, low consumption

either direct or reverse and is changeable on site without extra parts. The air relay valve is of the non-bleed force balance type, which gives a large output capacity with low air consumption.

A wide range of standard scales is available graduated in temperature or pressure, with equivalent metric units on the same scale. Temperature actuation is by mercury or vapour tube system, with a large range of bulb fittings, and pressure by a multi-coil Bourdon spring in bronze, steel or stainless steel.

Tick **No 174** on reply card

COUNTER

4000 counts/sec

An electronic counter and batch selector from H. & B. Precision Engineers Ltd. contain four Dekatron tubes, and a re-

Electrical Aids in Industry

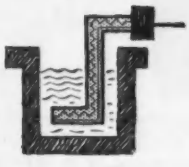
Data Sheet **No. 5**

Resistance Heating – 2

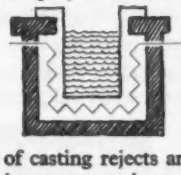
Electric resistance heating elements have been briefly described in Data Sheet No. 4, with two examples of their application in industry. This sheet lists some of the further applications which can be effectively dealt with by resistance heating.

Soft Metal Melting

Electric resistance melting is most commonly used for lead, tin, zinc, antimony, aluminium and their alloys—in processes such as tinning, type-casting, die-casting and lining bearings—at temperatures of up to around 800°C.



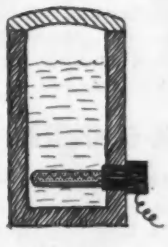
In most cases, sheathed elements are immersed directly in the metal, a more efficient method than applying heat to the outside of the containing vessel or pot. Immersion heating simplifies the application of lagging to the outside of the vessel, reducing heat losses and current consumption to a minimum. The elements are usually positioned near the inside wall of the vessel, leaving plenty of working space, but in a few cases, where the full volume of the pot is required, or where the metal to be melted is particularly corrosive, the elements are positioned outside the pot, often in contact with it.



In all cases, the precise temperature control that is so essential in soft metal processes is readily achieved by the use of electricity, and electric heating also leads to a reduction of casting rejects and metal wastage and a marked improvement in working conditions.

Liquid Heating

Electricity provides the ideal way of heating liquids such as water, oils, varnishes, plating, photographic and other solutions, and of melting and heating waxes and compounds, glues and pastes, tars and bitumen. Again, immersion heating is the method most commonly employed, but considerations of space or the nature of the liquid may sometimes necessitate the use of external heaters. Several types of devices are available to give precise and automatic temperature control, and lagging is again commonly applied to the vessel to minimise heat losses.

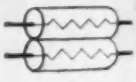


Fire hazards associated with inflammable liquids are invariably reduced by electric heating, particularly if immersion heaters can be used.

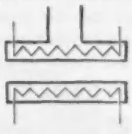
It is usually possible without difficulty to apply electric heaters, either immersion or external, to existing vessels.

Platen, Press and Roll Heating

Electricity offers the simplest and most convenient method of heating platens, dies and rolls. It gives the precise temperature-control characteristic of electric heating systems, with lower maintenance costs. Moreover, the relatively high temperatures required in some processes for maximum working speeds are reached without difficulty. Flexible electrical connections to moving parts give far less trouble than flexible pipe connections carrying hot water or steam.

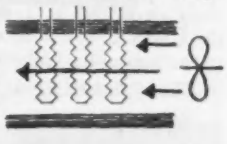


When electric heating is used, one or more presses can be operated without the necessity of keeping a boilerhouse staff at work.



Air Heating

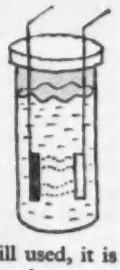
Streams of air, and of many other gases, can be heated most efficiently by electric resistance elements disposed across the duct leading to or from a fan. Heat is generated only inside the duct, just where it is required, and none is carried away through exhaust flues or pipes. Quick rise of temperature and precise temperature control are assured when electric resistance air heaters are used.



Electric Steam Boilers and Steam Raising

When steam is essential to a process, electrical steam raising can often be fully justified on economic grounds.

The means employed for bringing steam from a boilerhouse to the point of usage are often extremely wasteful, but where electricity is used the steam can be generated on the spot and losses from steam mains are eliminated. The efficiency of the electric boiler normally exceeds 96% and is practically constant at all loads, while the rapidity with which steam can be raised very largely eliminates banking losses.



Plant requiring process steam can be equipped with its own electric steam boiler, freeing the working space of steam mains just as individual electric motor drives free the factory of masses of shafting and belt drives.

Even where boilerhouse steam is still used, it is sometimes desirable for best results to boost the steam temperatures at the point of usage, to make up for transmission heat losses or to increase the superheat, and this function can most conveniently be performed by an electric resistance heater inserted in the steam line.

For further information get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available – "Resistance Heating" is an example; "Induction and Dielectric Heating" is another.

E.D.A. also have available on free loan a series of films on the industrial use of electricity. Ask for a catalogue.

EDA

CUT HERE

settable electromagnetic counter. Each tube has a selector switch which is numbered 0–9. Any number between 1–10,000 can be set up on the selector switches and constitutes a batch. Each batch is then counted up on the electromagnetic counter which has six digits. As each preset quantity is counted a set of change-over contacts open or close an external circuit, separating the batches, automatically repeating as required.

The counting rate is 4000 c/s with a batching rate of 5 batches/sec. The input can be from a photoelectric device or electrical contacts, according to customers' requirements.

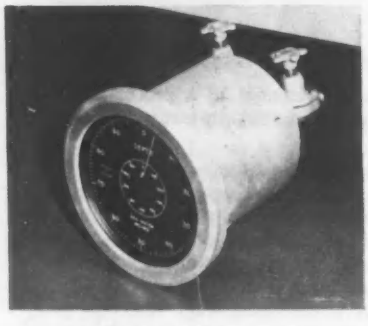
Tick **No 175** on reply card

PRESSURE GAUGE

a multi-turn instrument

Appleby & Ireland Ltd. have introduced a multi-turn 0–1000 in. H_2O pressure gauge based on the multi-turn absolute pressure gauge type A1.101. It was initially developed as a depth gauge for the U.K.A.E.

The instrument has a 6 in. dial presentation, scale graduation being 0–100 in.



Used here as a depth gauge

H_2O per rev of the large pointer, the small pointer indicating each 100 in. H_2O up to 1000 in. H_2O pressure. Temperature and barometric compensation can be provided over the scale range if needed. Standard accuracy is $\pm$ 1% f.s.d. but 0·3% f.s.d. accuracy can quite easily be entertained for master gauge purposes.

Tick **No 176** on reply card

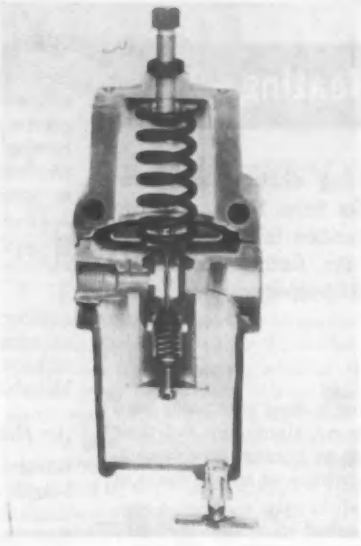
AIR FILTER REGULATOR

compact, efficient

The new No. 77 Mason Neilan air filter regulator set comprises a large capacity dripwell, porous ceramic cartridge-type filter, accurate pressure-reducing valve and relief valve, all in one light unit.

The rugged body is of die-cast aluminium with two mounting bolt holes. Elimination of alignment problems has resulted in a remarkably flat pressure/flow curve over a very wide range.

The No. 77 air filter regulator set can be supplied with or without outlet



Improved version, low-priced

and/or inlet pressure gauges. The maximum inlet pressure is 250 lb/in²; reducing pressure range is 4–50 lb/in²; inlet and outlet connexions screwed female; weight 2½ lb, and overall height 8¼ in.

Tick **No 177** on reply card

SELECTOR VALVE

up to six-way distribution

A new selector valve has been designed by Drallim Industries Ltd. and provides a method of distributing gases and liquids between a number of independent or inter-connected ports. Present range covers two to six-way distribution. The selectors are moderately priced. Operation of the selector is controlled by a cam shaped central spindle which is contacted by valve stems contained in each of the connectors. Standard selectors are supplied with ¼ in. B.S.P. and ⅜ in. B.S.P. connectors. Working pressure—high vacuum to 200 lb/in². These selector valves are light in operation and are therefore suitable for use in conjunction with pneumatic rams or other types of automatic control.

Tick **No 178** on reply card

ANALOGUE COMPUTER

accuracy better than 0·01%

Short Brothers & Harland Ltd. are about to market a large multi-unit computer. The component absolute accuracy is claimed to be better than 0·01%.

The basic instrument is a 112-amplifier linear computor, with up to nine special non-linear components if desired. The computer comprises seven standard racks, the three control racks being fronted by a double pedestal desk. The transistorized power units are located below desk level and the measuring equipment and non-linear components (if any) above desk level. The amplifier units are of new design having a main amplifier gain greater than 105 and a drift over 24 h at unity gain better than 10 μV (drift correction factor 1000).

One of the features of the design is the patch panel by which the active and passive outputs and inputs are interconnected. The connexions are made by single-pin plugs and single-patch cords. Although up to 20,000 different connexions are possible and up to 100 cords may be employed per panel, none of the cards cross.

A new design of selector panel enables any amplifier output to be connected to any of the measurement channels, or any of the servo-set potentiometers to be set-up from the control desk by means of selector buttons and setting keys. Thirteen measurement channels are provided which, apart from the mandatory digital voltmeter, can be arranged to suit an individual customer's requirements. The digital voltmeter and associated printer displays a four-digit fraction of 100 V and is accurate to 0·01%.

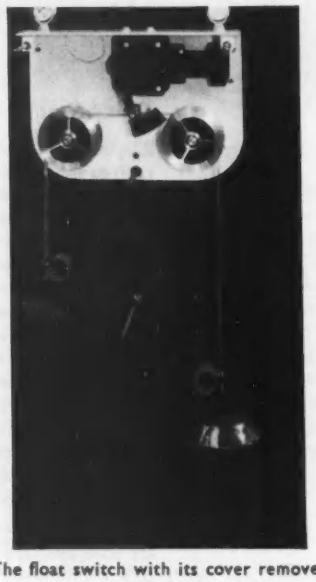
A comprehensive checking system has been devised which ensures a rapid check of all circuits and connexions, the sequence being automatically stopped if any errors are detected.

Tick **No 179** on reply card

FLOAT SWITCH

with novel plastic belt

A float switch has been developed by Megator Pumps and Compressors Ltd. The whole unit, comprising switch, float

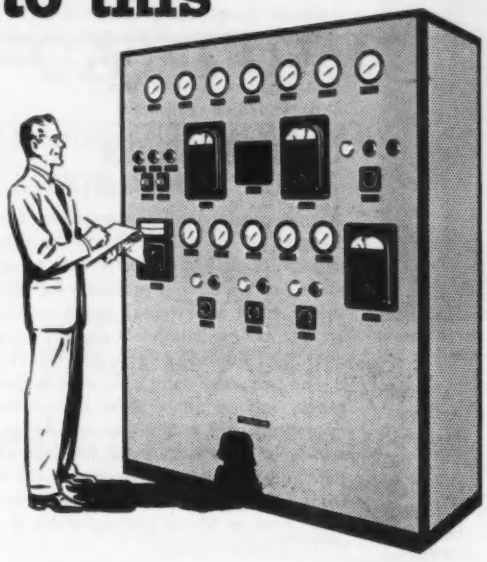


The float switch with its cover removed

gear and counterweight, forms a single assembly for mounting. A flat nylon belt is used instead of the usual wire rope and

From this

to this



and everything between!

A single thermometer to a complete installation. We produce a wide range of industrial indicating, recording and controlling instruments. Our service includes a contracts department for the engineering and installation of complete instrumentation schemes.

Brass-cased tank and pipe thermometer

Mercury-in-steel dial thermometer, distance-reading type

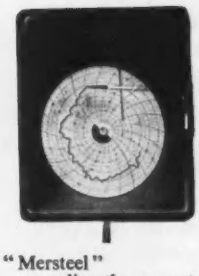
Disc chart pressure recorder

10" multipoint pyrometer indicator

Air-operated mercury-in-steel temperature transmitter

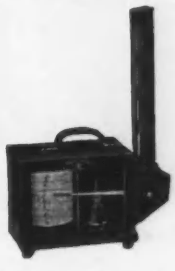
Air-operated compound controller

Dial Pressurestat



"Mersteel" recording thermometer

Valve positioner



Recording hair hygrometer

INSTRUMENTATION BY—

NEGRETTI & ZAMBRA

NEGRETTI & ZAMBRA LIMITED 122 REGENT STREET, LONDON W1

Manufacturers of instruments for the indication, recording, controlling of:— temperature, pressure, liquid level, volume, specific gravity, humidity, etc. Also meteorological and aircraft instruments.

Tick No 87 on reply card for further details

this allows the actuating stops or fingers that engage the switch trip lever to be mounted on the upper side of the belt, and to pass over the pulleys in operation. A 20 ft nylon belt is supplied as standard, punched at 3 in. intervals for easy adjustment of the switch-actuating fingers which fix the operating levels. The switch is rated at 10 A 440 V a.c.
Tick **No 180** on reply card

PNEUMATIC RELAY

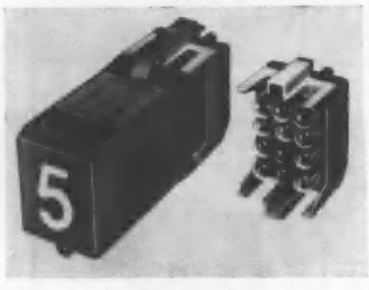
gives constant differential

Five different types of constant differential relay made by Sunvic Controls Ltd. are now available with a built-in variable area flow meter (Rotameter) and a needle valve. These relays can be used to ensure a constant bubbling rate of purging air or gas in air reaction systems for liquid level measurement. No liquid is used in the purge flow controller and so no maintenance is required. Instead of visual indications of purge rate by bubbling, an accurate flow meter, with easily read calibrations is provided. The unit is rated at 50 lb/in² static pressure and tested at 100 lb/in² static pressure.
Tick **No 181** on reply card

INDICATOR

in-line, optical

An in-line indicator has been added to the range of products marketed by R. B. Pullin & Co. Ltd. Known as the Aldis Digilite (A.100), it uses twelve lamps and employs an optical projection system. The angle of view is 75° off axis in all



The bulbs can be easily replaced

directions; the figure size is 1·2 in. high with an overall height of 3 in. The figures read 0 to 9 plus 2 decimal points. The lamps are 6·3 V 0·3 A.
Tick **No 182** on reply card

ELECTRONIC FLOWMETER

of the magnetic induction type

The Rochar range of electronic flowmeters for the measurement of instantaneous rate and integrated volume of flow of liquids is now being marketed by Metrix Instruments Ltd.

The volumetric transducers employed are of the magnetic induction type and

The flowmeter and its associated frequency measuring equipment

consist of a cylindrical body, through which the liquid passes, and a free rotor with helicoidal blades the rotational speed of which is proportional to the rate of flow. The alternating signal output from the transducer has a frequency in c/s equal to the rev/sec of the rotor.

The transducers are accurately machined from heavy-duty alloy designed to withstand corrosion and are satisfactory for use with nitric acid, liquid oxygen, jet and rocket motor fuels etc. Operating temperatures from −200 to +150°C are permissible and models for use at higher temperatures are under development. The transducers are small, easy to install and are independent of vibration, position of mounting, and pressure of liquid flowing.

The range of flow rate covered is from 20 to 100,000 l/h and calibration can be effected in any units required.
Tick **No 183** on reply card

POWER DRIVES

a miniature, versatile range

A series of miniature power drives has been developed by Tiltman Langley Ltd. They can be used as clutches, freewheels, backstop or dual drives. The control of the non-slipping clutches is by a pawl, which can be operated mechanically, pneumatically, hydraulically or electrically. The clutches are 1 in. long and 1·5 in. in diameter, and can transmit 20 lb-in. In certain conditions the clutches can transmit up to 100 lb-in. A kit of parts can be supplied from which a clutch, freewheel, backstop or dual drive can be assembled.
Tick **No 184** on reply card

PNEUMATIC RELAY

a maximum auto-selector

A relay which will accept two signals in the 0–100 lb/in² range and always pass the higher signal has been added to the range of pneumatic relays produced by Sunvic Controls. Known as the model 58S, it is intended to complement the Sunvic Model 61F booster relay which is a minimum auto-selector.

The Model 58S relay will operate in ambient temperature from −40°F to +180°F. Maximum operating pressure is 100 lb/in². As there is no retransmission, there is no time delay.
Tick **No 185** on reply card

OSCILLATOR-AMPLIFIER

high power, versatile

A high-power oscillator/amplifier, from Airmec, is basically a power amplifier capable of delivering 150 W into a wide variety of loads, with provision for being driven from an external signal or from an internal oscillator continuously variable over the range 30 c/s to 30 kc/s.

The frequency band is covered in three ranges and on all of them the calibration accuracy is ±2%. The amplifier sensitivity is 0·1 V r.m.s input for full output. The frequency response is ±0·5 dB from 100 c/s to 5·0 kc/s, not more than 4 dB down at 30 c/s, and not more than 10 dB down at 30 kc/s.

The price complete is £200 and delivery is from stock.
Tick **No 186** on reply card

FLUID VALVE

with servo assisted solenoid

A servo-operated solenoid valve (type ASV) has been put on the market by Ether Ltd. The solenoid controls a pilot valve, supplied with an auxiliary pressure

For pressures up to 100 lb/in²

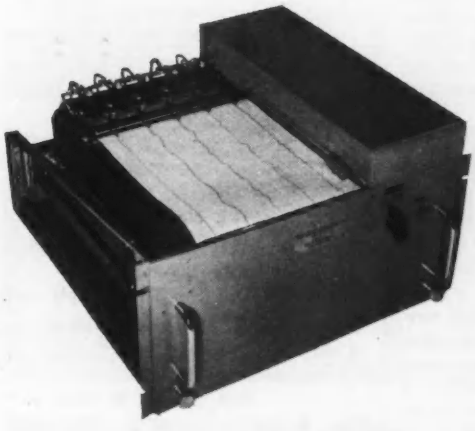
supply, which in turn operates the main valve. Main valve sizes up to 1 in. are available at pressures up to 500 lb/in², depending on the auxiliary supply pressure.
Tick **No 187** on reply card

CAPTURE

TRANSIENT PHENOMENA FOR GOOD WITH

High-speed

PEN RECORDERS



Continuous recording of rapid, transient or oscillatory phenomena is made possible with Kelvin Hughes High Speed pen recording instruments. A wide range of instruments is available including new units which will permanently record up to 8 variables simultaneously. When used in conjunction with special Kelvin Hughes bridge amplifiers and power units, the recorders will measure strain, force, displacement, drag, pressure, acceleration and similar variables, providing instantaneous permanent recordings. Rapid response, versatility and dependability make them well suited for research work in aerodynamics, rockets, hydraulics, computers, and countless applications in industry, including civil engineering, mining, production testing of motor cars and tractors.

Ruggedly built and insensitive to external vibrations, Kelvin Hughes pen recorders will operate effectively under the most exacting conditions in vehicles, aircraft, and where heavy industrial plant is operating.

Please write for technical literature. Kelvin Hughes specialists are freely available to advise on any particular application for single- or multi-channel recorders in industry.

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ELECTRIC RELAY

a miniature, high-speed unit

A low current version of an existing miniature high-speed sealed relay has been developed with an activated carbon getter inside the container to absorb the slight organic vapours that remain after sealing and which cause contact contamination. Known as the type 130, the relay has been developed by Siemens Edison Swan Ltd. Of the single change-over type, the relay is made for various voltages between 1·2 and 48 V d.c. The contacts are of platinum, and contact resistance is 0·1 ohms or less. At 100 operations/sec the relay has a life of 300 h minimum, though 4000–10,000 h are usual; a recent continuous life test showed approximately 3600 million operations.

Tick **No 188** on reply card

QUICK LOOKS

English Electric has added to its range of relays a negative phase sequence relay designed to protect large alternators against damage from unbalanced loading or faults.

It has been designed to shut down a large alternator quickly before it can be damaged and also to avoid unnecessary tripping. As negative phase sequency heating varies according to the type of alternator and method of cooling, the relay has a time-current characteristic approximately matching the heating characteristics of any alternator with which it is used.

Tick **No 189** on reply card

Marconi Instruments Ltd. have announced the introduction of the TF 1330, a new general-purpose oscilloscope with all the features required for detailed viewing and precision measurement of waveforms. Its frequency response extends from d.c. to 15 Mc/s and sensitivity is variable in seven steps from 50 mV/cm to 50 V/cm; a signal of 300 mV will provide full coverage of the 6 × 10 cm screen.

Tick **No 190** on reply card

Secondary standard silicon solar cells are available from International Rectifier Co. (Great Britain) Ltd. These cells are designed for calibration of artificial light sources in terms of solar energy radiation. Each cell is of at least 9% conversion efficiency, and is accurately calibrated to its exact efficiency rating. The price is approximately £32 and delivery takes 5–6 weeks.

Tick **No 191** on reply card

The Hilger D290 grating monochromator gives 15,000 lines to the inch and gives a reciprocal dispersion of 70 A/mm. The slits, variable in width from 0 to 1 mm, are of the simple unilateral form and are so coupled that whatever their width, the peak wavelength of the transmitted radiation remains constant. The wavelength can be varied from 200 to 1000 mu and is controlled by a knob with an indicator reading to 1 mu.

Tick **No 192** on reply card

The Paraphone, from Epsylon Industries Ltd., is designed to operate unattended and give a total of 40 h recording or replay before repetition. A tape speed of 3¾ in./sec is employed to give a frequency response of 60 c/s to 6 kc/s within the 3 dB points. A two-track head is used on a cam assembly giving twenty positions for the heads on a 1 in. head. The equipments costs about £400.

Tick **No 193** on reply card

Research and Control Instruments Ltd. have announced the introduction of a cold box installation. This is believed to be the first of its kind in the world with a net content of about 400 l for temperatures down to −160°C. Refrigerating capacity at −100°C is 4400 B.t.u./h and 2560 B.t.u./h at −160°C.

Tick **No 194** on reply card

International Rectifier Co. (Great Britain) Ltd. now have available a new series of low-cost 25 to 35 A, 50 to 500 V peak-inverse-voltage rated silicon power rectifiers designed specifically to provide exceptional performance (including operation to 130°C base temperature) in commercial equipment applications.

Tick **No 195** on reply card

A broad-band millivoltmeter has been introduced by Research and Control Instruments Ltd. It has a frequency range of 2 c/s to 1 Mc/s and a high sensitivity (1 mV for 300 V f.s.d.).

Tick **No 196** on reply card

Newman Industries Ltd. have recently commenced production of an automatic oil burner control (type 7540). It is constructed on a plug-in basis, and the manufacturers claim it sells at about 20% below conventional units.

Tick **No 197** on reply card

Pipe couplings for use at pressures up to 200 lb/in² have been brought out by Drallim Industries Ltd. The fittings are normally made in brass, in sizes for use with $\frac{5}{32}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{1}{2}$ and $\frac{5}{8}$ in. o.d. pipes.

Tick **No 198** on reply card

Counting Instruments Ltd. have a new non-reset electromagnetic counter (series 1200). The counter is compact and tamper-proof. It sells for approximately 25s for quantities of 500, and delivery is 8–10 weeks.

Tick **No 199** on reply card

Shandon Scientific Company Ltd. has recently announced the introduction in this country of two low-priced air velocity meters. They are respectively the Florite, a bridled vane anemometer, and the Floret, a small pocket indicator.

Tick **No 200** on reply card

INDUSTRIAL PUBLICATIONS

40-page brochure 'Auto-Klean in Industry' details Auto-Klean Strainers range of **filters** and their more unusual applications in industrial engineering.

Tick **No 201** on reply card

Specification sheet (S800-1) on Honeywell Controls' **Electr-O-Vane control unit.**

Tick **No 202** on reply card

Power System Computers Ltd.—illustrated leaflet of their **analogue network analysers.**

Tick **No 203** on reply card

Publication from Solartron gives details for training radar operators and controllers by **radar simulation systems.**

Tick **No 204** on reply card

Solartron literature on a direct-coupled operational **amplifier** (AS 621.2) and **pressure transducers** (NT 4-313 and NT 4-980).

Tick **No 205** on reply card

Catalogue of useful data on **bellows expansion joints** including glossary of terms. Teddington Aircraft Controls.

Tick **No 206** on reply card

Sound Diffusion (Auto-Thermatic) Ltd. folder contains stencilled sheets describing the '**Datafonic**' **system.**

Tick **No 207** on reply card

An R.C.A. booklet briefly reviews basic parameters of magnetic circuits, switching applications of magnetic cores and technical data for ferrite cores and memory-circuit components.

Tick **No 208** on reply card

Price list and news sheets of hermetically sealed **transformers and chokes**—Woden Transformer Co. Ltd.

Tick **No 209** on reply card

Bi-monthly newsletter 'Rectifier News'—International Rectifier Co. (G.B.) Ltd.

Tick **No 210** on reply card

Leaflet from Polypenco Ltd. on Nylaflow pressure hose and tubing.

Tick **No 211** on reply card

George Kent publication (TP5041)—'Control of Flame Characteristics by Wobbe-Index Value.'

Tick **No 212** on reply card

The Hewlett-Packard Journal (July-August) deals with a d.c. vacuum-type voltmeter with extended sensitivity and stability.

Tick **No 213** on reply card

Two leaflets describing briefly the Baird & Tatlock fraction collector and the chromatographic drying oven.

Tick **No 214** on reply card

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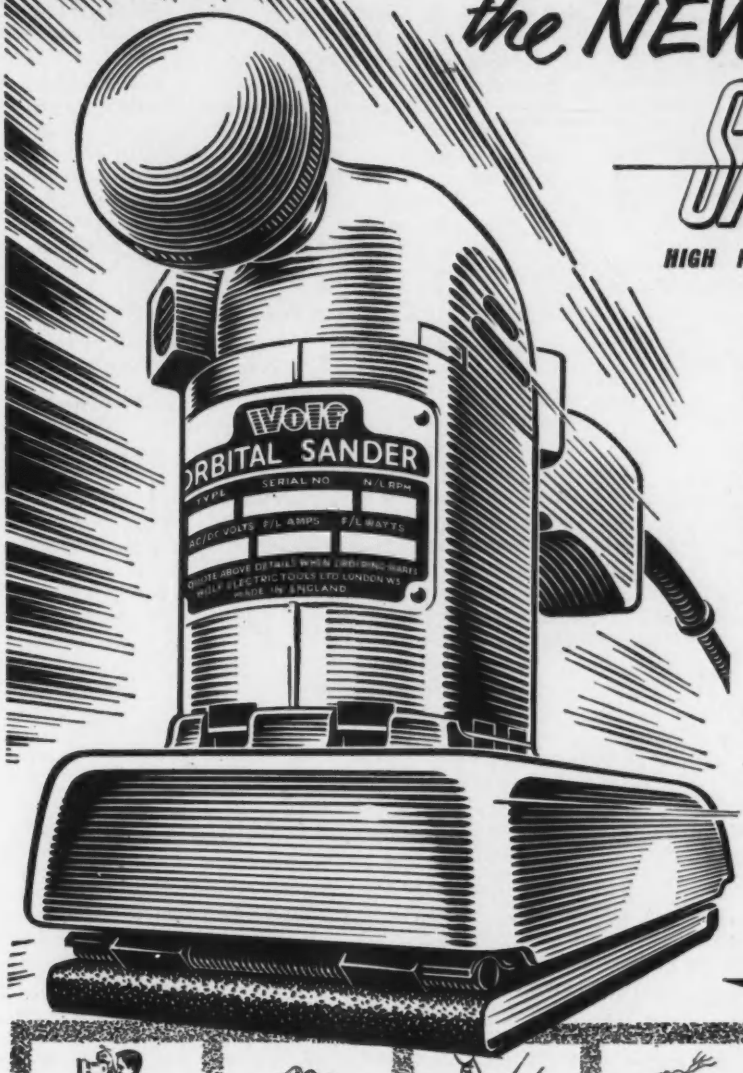
THE HIGH FINISH SANDER THAT INDUSTRY CLAMOURS FOR!

the NEW WOLF SANDSWIFT

HIGH FINISH ORBITAL SANDER TYPE OR37



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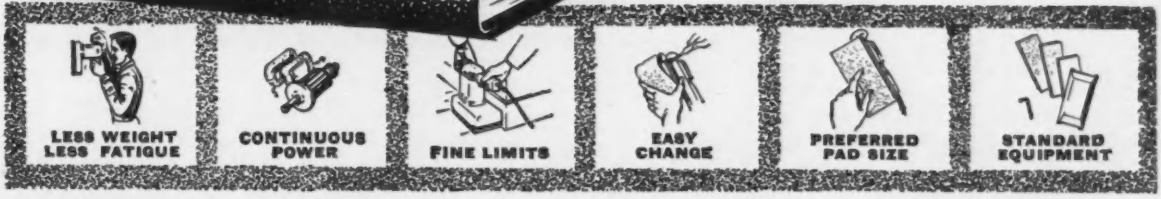

Wolf

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AR7

For your bookshelf

La cybernétique éblouissante

What is Cybernetics? *by* **G. T. Guilbaud.** *William Heinemann. 1959. 134 pp. 10s. 6d.* ★ 252

Although it is nowhere obvious that this book is a translation from the French, one of the most exciting things in it is that a metaphor from the pilotage of a ship indicates the link between the eighteenth-century use of *la cybernétique* for 'the executive branch of civil government' (a usage based on Plato) and its modern French usage for 'cybernetics.' In the author's view, *la cybernétique* is the stratum between policy and value judgments on the one hand and routine or mechanical operations on the other hand. The book is therefore concerned first with automatic control systems, in connexion with which it stresses the importance of network theory and discusses feedback; secondly with the group of topics which has been welded by Shannon into a mathematical theory of communication (selective information and its measurement, entropy, sampling, communication in the presence of noise); and thirdly with the statistical theory of games and strategies (which it discusses under the misleading chapter heading of 'Towards Unification').

To the reader having some acquaintance with this field of work it is most interesting to see how the author tackles these subjects while keeping the text non-mathematical. But the book is aimed at the non-specialist reader, and it is doubtful whether he will be much wiser at the end. Many interesting topics are raised, but there are no illustrative applications and no thread of coherence running through the book: the reader who sees many facets of cybernetics but no inner structure may be dazzled rather than enlightened. D. A. BELL

Ponderous, but worth pondering

The Landmarks of Tomorrow *by* **Peter F. Drucker.** *William Heinemann. 1959. 204 pp. £1 1s.* ★ 253

Control engineers, particularly those who have read any of the author's earlier works and who are interested in studying what effects their technology have upon the world, will welcome this stimulating new book. A very wide horizon is covered but no claim for completeness is made. Three large areas are considered representing a goodly portion of human life and experience, namely:—the new view of the world, the new concepts, the new human capacities; the new frontiers, the new tastes and opportunities; and the human situation.

Drucker shows that everyone of our disciplines has moved from cause to configuration, which can never be reached by starting with the parts (for example automation or management), and none of these new concepts has any causality to it. This argument on what the new integration needs to be should interest control engineers, as will the chapter on 'From progress to innovation.'

Some parts of the book may appear ponderous or repetitive but it can nevertheless be highly recommended to all, let us hope the majority, who are concerned about the direction in which modern society progresses under the stimuli of present day science and technology. L. LANDON GOODMAN

Less and less about more and more

Industrial Electronics Handbook *edited by* **William D. Cockrell.** *McGraw-Hill. 1958. 1408 pp. £8 14s. 6d.* ★ 254

The first question that one feels prompted to ask on skimming through the pages is, 'Why is it called the "Industrial Electronics Handbook"?' For this well produced volume covers a wider range of material than such a title suggests. Perhaps there is in the United States a breed of *electronics engineers*, called by that or some other name, who are separated by administrative or psychological barriers from their fellow technologists. Such men, cut off in whatever way, might like to have one compact reference book embracing both their own and related crafts.

Although one cannot help wondering whether a number of specialized 'handbooks,' dealing in great detail with their specialities, might not be more useful in most cases than a single work of this kind, one must admire the ability that has been employed in condensing so much information to fill, relatively, so little space. There are not many electronics engineers of the reviewer's acquaintance who would be likely to require data on, say, water hammer; but a reference to water hammer will be found in the 'Industrial Electronics Handbook.' The contributors all seem to appreciate that they cannot compress the whole of their lore into their allotment of pages, and they give bibliographies to guide interested readers to more detailed treatments of the particular subject they touch upon. A.E.E.

The Yanks have a word for it (usually)

Dictionary of Guided Missiles and Space Flight *edited by* **Grayson Merrill.** *D. Van Nostrand. 1959. 688 pp. £6 11s. 6d.* ★ 255

There was a time when a reviewer would call all thoroughness or love of detail 'Teutonic.' To-day the epithet might well be 'American.' There has been a stream of specialized reference books and dictionaries from the other side of the Atlantic, some of them more useful than others, but all indicating that at least a need has been recognized. There is no doubt that the advance of technology has changed not only our material way of life, but also our way of talking and writing about it, and language has been enlarged (though not always enriched) to embrace the new ideas and devices that have been invented.

The volume under review actually forms part of a series on the principles of guided-missile design, and as such it serves admirably and compactly one of the purposes of an index. It aims rather higher than this, however, and in his preface the editor claims that the book can be used as an encyclopedia and a source of exact definitions. In the former capacity it often succeeds rather well. There are, for example, some useful tables of missiles and of both natural and artificial satellites. But as a source of exact definitions the work is less satisfactory. *Eccentricity*, to quote one instance, is defined for only one of its (relevant) technical meanings. Thoroughness goes awry in other places also. Thus the reader is told that ISW means inter-submarine warfare and that SSM-A-12 is Lacrosse, but a word like *cybernetics* does not appear.

The Dictionary is very clearly printed in type that is perhaps a little too large. Inevitably this lack of modesty is reflected in both the size and the price. J. T. STERNE

Books received

Servomechanism Fundamentals *by* **Ben Zeines.** *McGraw-Hill. 1959. 257 pp. £2 3s.* ★ 256

Insulation for Small Transformers *by* **J. H. Mason** *and* **C. G. Garton.** *Electrical Research Association. 1959. 93 pp. £1 17s. 6d.* ★ 257

Bulletin of Special Courses in Higher Technology. *London and Home Counties Regional Advisory Council for Higher Technological Education. 1959. 136 pp. 3s. 6d.* ★ 258

B.S.I. Annual Report 1958-59. *British Standards Institution. 1959. 268 pp. 7s. 6d.* ★ 259

Design of Transistorized Circuits for Digital Computers *by* **A. I. Pressman.** *Chapman & Hall: London. Rider: New York. 1959. 316 pp. £4.* ★ 260

* Tick the relevant number on the reader information card for further information on any book reviewed above.